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The Human Project

ARTICLE BY JOE FORDHAM

British thriller writer P.D. James' 1993 novel *The Children of Men* — a speculative tale of near-future England torn apart by a global infertility pandemic — had a slow gestation as a feature film. After nine years in development with five credited screenwriters, the production finally took root in the imagination of director Alfonso Cuarón shortly before he became involved with the third *Harry Potter* film. The lengthy preproduction period allowed the production to develop narrative and technical issues required to bring the intimate futuristic drama to the screen. "Alfonso wanted to film incredibly long takes that needed a great deal of planning and designing," recalled Double Negative visual effects supervisor Frazer Churchill. "He and his director of photography, Emmanuel Lubezki, likened the shooting style to *The Battle of Algiers*, the *Italian* neorealist movie, which they loved for its naturalism and its documentary feel. It was a tall order to shoot visual effects shots in that style, so it necessitated our involvement at a very early stage, while the script was being written."



Cuarón's vision of future England was a landscape of recognizable technology that had gone to seed, photographed with an all-encompassing roving camera. "Alfonso wanted to catch what he called 'moments of truthfulness,' where the camera panned past characters to wander off exploring the environment," said Churchill. "It was a visual motif that used wide-angle lenses, which made every frame say something about the protagonists in their world. A lot of thought went into setting up extraordinarily long shots that were very carefully orchestrated and designed."

The film opens with its first extended scene on London's Fleet Street, November 16, 2027. Theo Faron (Clive Owen) exits a crowded coffee shop, leaving other customers staring at television news reports of the death of the planet's youngest citizen — a teenager. Futuristic traffic passes by on the street. Theo attempts to sip his coffee. Without warning — in what appears to be a single, handheld camera take — a terrorist bomb explodes, destroying the café Theo just vacated.

The production filmed the scene in the heart of London's business district during a two-day weekend shoot. "On Day 1, we shot interior, with Clive in the café and walking out," Churchill explained. "On Day 2, special effects supervisor Paul Corbould's team reset the café to explode with air mortars, rubble and special effects dirt. We also redressed the people we'd just established in the café in the opening of the shot as wounded and amputees. We broke the shot in two because it was so complicated to choreograph. First assistant director Terry Needham and stunt supervisor Steve Dent coordinated approximately 300 extras, 80 vehicles and 20 special effects cues in the shot. It was an enormous amount to orchestrate in a very time-restrictive location."

To join the two parts of the shot, Churchill devised an invisible transition that catered to Cuarón's roving camera motif. "Alfonso didn't want the 'waiter with the tray of drinks' approach, where a

random passerby wiped frame at the cut,” said Churchill. “Instead, we decided to make the blend where the camera momentarily panned off Clive, becoming his point of view as he stepped outside the café. *In the moment we panned off him, we did a digital transition around the café doorframe.*” Churchill used the motion of a bus passing by the café door to help disguise a transition in background action, providing Double Negative with a natural background wipe for the latter part of the shot. “As Theo stepped outside, we were seeing the pavement and people from Day 2 composited with the bus from Day 1. As the bus passed by, the rear of the bus wiped on the Day 2 buildings and traffic.”

To facilitate the matchmove, Double Negative shot high dynamic range lighting reference on set and employed a Total Station architectural survey tool to sample key points of location geometry. CG supervisor David Vickery and 2D supervisor Andy Lockley then aligned the plates and blended images so the camera appeared to follow Theo along the busy street in one fluid move.

For the explosion, Double Negative inserted an element of two stunt performers on a jerk rig, filmed against greenscreen on the backlot at Pinewood Studios, and tracked the characters in front of the café, receiving the full brunt of the blast. “What you see in the shot is pretty much what happened on the day,” commented Churchill. “We added bits and pieces of glass and specific debris, but we didn’t beef up the explosion at all.”

Double Negative also tracked animating advertisements into the scene, simulating omnipresent public service announcements. London design company Foreign Office created futuristic media content, including commercials for designer drugs, a Gap-style campaign for ‘Ruf Pets’ animal clothing — illustrating the population’s proclivity for pampering pets as child surrogates — and Big-Brother-styled PSAs for ‘Homeland Security,’ fertility testing and state-issued suicide pills. David Vickery integrated the moving images onto the sides of buildings, vehicles, TV screens and billboards throughout the film. “We had greenscreens on buses,” said Churchill, “but no greenscreens on the buildings, which would have been too big to erect. We matchmoved the street and tracked in ads with a little bit of translucency, revealing structures through the screens, light reflecting and layers of dirt. We spent a lot of time trying to imagine how far advertising technology might have advanced. It was not 30 years advancement; it was 15 years advancement and 15 years of neglect. We built in a lot of imperfections and broken cells into the displays.”

Later in the film, Theo meets with an acquaintance at the Ministry of Art, an imposing edifice that protects international art treasures in the renovated shell of Battersea Power Station. The production filmed establishing shots at the deactivated power station bordering the River Thames. Frazer Churchill then selected a disused bridge on the M3 motorway to represent a connecting roadway long enough to span the river. Production designers Jim Clay and Jeffrey Kirkland dressed the bridge with a military checkpoint. Using a FireWire connection from the motion picture camera video tap, Churchill lined up

image

Near-future London was depicted in the opening of Children of Men, a dystopian drama set during a global infertility pandemic that threatens the human race with extinction. Beginning with a lengthy handheld shot, director Alfonso Cuarón followed the film’s protagonist, Theo Faron (Clive Owen), as he exits a café, walks down the street, and then reacts in alarm as the eatery he just left is blown apart in a terrorist explosion. The scene set the mood for the film’s gritty realism, made possible by the flawless integration of visual effects by Double Negative and Framestore CFC.

image

the camera angle on the bridge with the Battersea plate, and Double Negative blended images with digital matte painting. “Neil Miller, our concept artist and matte painter, extended the roof with a glass structure,” commented Churchill. “He added windows and surrounding buildings. Neil is also a sculptor so he put one of his own art pieces on the waterfront.”

As she attacks, the car folds the hood out from the bed off, also repurposed London's Fleet Street for a coffee and dining furniture behind futuristic special-effects storefronts, perched in the 80 Central London area. 3D extensions include digital details added directly to the streets. Double Negative layered double the black and white as Double Negative of the stunt performed on Clive Curran's character's life, filmed on the day of the location shoot, and double plates and digital effects from the smoking explosion, filmed on Day 2.

Double Negative enhanced Ministry interiors, adding details to an entrance hall shot in the turbine hall of the Tate Modern art gallery, and adding translucent windows to a room housing the damaged remains of Michelangelo's David — a full-scale prop given a digital prosthetic tibia. Cuarón filmed Theo's penthouse-level meeting in a Pinewood set with greenscreen representing a floor-to-ceiling window overlooking the city. For window views, Churchill and second unit director Peter Hannan ascended a leviathan Federal Signal Bronto Skylift crane overlooking Battersea Power Station and shot tiled plates of London. Double Negative stitched plates together in the studio's proprietary PlaneIt cyclorama software and added subtle matte painting details. CG artist Philip Johnson built a roof extension and a 40-foot balloon pig floating between the power station chimneys. “We were putting together the painting when Alfonso said, ‘I want to see the Pink Floyd pig!’” Churchill recalled. “The idea was that the Ministry had collected icons of 20th-century art, and the balloon pig from the cover of the Pink Floyd album *Animals* was hugely iconic to that location. We found photos and plans of the pig online and built an exact replica. It was a 3D build, animated, lit and textured with a ‘balloony’ texture that could be buffeted by wind to keep it moving all the time.”

Armed with transit papers procured from his Ministry contact, Theo and his ex-wife Julian (Julianne Moore) collude to extradite Kee (Clare-Hope Ashitey), a fugitive from the law who is pregnant with what may be mankind's last child — or possibly its salvation. A turning point occurs during a road trip through the countryside when rebels attack and kill Julian and implicate Theo in the shooting deaths of police officers summoned to the scene. Cuarón filmed the action in a show-stopping camera setup lasting more than four minutes, panning and tracking around five performers inside a Fiat Multipla compact van.

Early discussions of how to shoot the scene eliminated thoughts of using traditional process photography. “Shooting on a greenscreen stage and then shooting background plates would have given us the ability to put the scene together in a neat and controlled way,” allowed Churchill. “But it would have lost all the subtleties of lighting that occur on location. The van was also under ambush, with people running out of bushes and making contact with it, which would have been very difficult to create on greenscreen. There are lots of greenscreens in the film, which are undetectable due to Emmanuel Lubezki's naturalistic lighting; but, for this scene, we decided we would never get the result we wanted on a stage.”

To shoot the scene on location, the production employed a custom camera-car rig resembling a large motorized four-wheeled flatbed, with drivers front and aft, flanking a cutaway section of a Fiat Multipla, on top of which the camera team rode in a large box secured to the vehicle's roof. The rig

allowed an Arri 235 to hang through the Multipla's roof and maneuver around the cabin on a Doggicam Sparrow Head mount attached to an overhead Two-Axis Dolly engineered by Gary Thieltges, founder of Doggicam Systems. "It was an extraordinary rig that had 13 people riding on it as it traveled around," said Churchill. "Two drivers were seated in go-kart cockpits front and back. The van was in between them, with our five actors inside. The camera compartment — where Alfonso, Emmanuel Lubezki, who operated the camera, and Frank Buono, the Two-Axis Dolly operator, sat — was on top of that. Terry Needham, Steve Dent, the video assist operator and I rode on running boards outside of the rig."

Hinged seating in the vehicle, and a windshield that could swing aside, allowed the camera to pull back for wide angles of all five performers without breaking the illusion of the confines of the vehicle. "A lot has been made of the fact that the adjustable seats and camera rig enabled the scene to be shot in one take," Churchill observed. "Most of the press about the film has not mentioned the role of visual effects. Alfonso had a tremendous appreciation for what we were able to do; but until now he asked us not to talk about the technical aspects of the achievement, to avoid overshadowing the artistic impact of the scene. The fact is, the sequence took two months to plan, was staged in three locations, and took eight days to shoot. The reason the camera was able to move so freely is because we did the shot in six sections, and sometimes all the actors weren't in the car. As the camera swung around, we used pans to do digital transitions to the next day's photography. The camera and seating rigs were very versatile, but the scene was really made possible by the digital transitions."

The shot began with a long dialogue sequence, shot on a length of road bordering Bourne Wood in Surrey. A tiny digital prop assisted an early detail in the scene — Theo catching, in his teeth, a ping-pong ball Julian has playfully shot from her mouth. Julianne Moore propelled a real ping-pong ball toward Clive Owen. Andy Lockley, who oversaw digital compositing of the sequence over the period of one year, then painted out the ball and tracked a 3D duplicate into Owen's open mouth.

Subsequent scenes in which rebel assailants roll a burning car out of the trees as a roadblock were filmed on private land near Aldershot. A further section of forested road and open farmland was then required to provide access for police vehicles following the attack. Churchill's team gathered surveys of each location and captured cyclorama views of moving backgrounds using three motion picture cameras mounted on a flatbed truck. "Our transitions had to work on the inside and the outside of the car," stated Churchill. "We were able to make our interior transitions work reasonably smoothly by matchmoving shots and rebuilding parts of the car in 3D; but on the outside, we also needed plates of every environment we filmed in. We didn't completely replace the background all of the time, but we did completely replace the background through certain sections of the shot — sampling 100 frames here or there as a transitional matte painting, if weather conditions or the type of background vegetation did not match from day to day."

To conceal the camera compartment visible from within the Mutlipla interior, 3D sequence lead Aleks Pejic created a CG car roof interior with interactive lighting and animated shadows. Andy Lockley then composited 3D car sections, masking transitional blends between doors, windows, seats and dashboard. The transitions facilitated action staged around the camera vehicle in elaborately choreographed takes — with rebels blocking the road by rolling a burning vehicle out of

the trees, then charging at the van as the Multipla reverses, opening fire, killing Julian, pursuing the retreating vehicle on motorbike, and finally relenting only when armed police arrive — all apparently captured in a single, claustrophobic take.

For the rebel attack, Paul Corbould's team rolled a practical burning car into the road on location, and provided a rubber rock thrown at the Multipla windshield. Double Negative replaced the dummy rock with a digital Molotov cocktail and tracked in a pyrotechnic element of a burning gasoline bag exploding against glass. When the gunmen open fire, Double Negative punctured the windshield with a CG bullet hit. The Corbould team then provided a greenscreen dummy head plumbed with blood that compositors utilized to digitally enhance a blood squib effect on Julianne Moore.

Enraged, Theo shoves open his car door into an attacking motorcycle. Cuarón shot the stunt on location, with stuntmen falling into undergrowth. Double Negative generated a digital motorcycle, rider and gunman passenger, extending the live stunt as the bike's front wheel flipped off the ground, spilling the motorcycle and gunman in a fatal crash. The Multipla windshield then spiderwebs with digital splintering effects tracked into the plate, and shatters with a full dynamic simulation of imploding glass timed to break with an animated camera shake simulating impact with a pothole in the road.

Confronted by the police, the Multipla halts and Theo exits the vehicle, followed by the camera, which then lingers by the roadside as the confrontation concludes. "We shot Clive exiting the camera car," said Churchill. "Then, on another day, camera operator *George Richmond* operated a handheld camera exiting a real van. We did a transition on the rear part of the window frame of the open door, so when the camera looked back it saw the Multipla without any rigging. The van then drove away, creating the illusion that there was no trickery at all."

Theo and Kee arrive at Bexhill refugee camp — a heavily fortified internment facility on the English coast — where Kee gives birth in a derelict hotel room. Animatronic supervisor Nick Dudman created a prosthetic rig for the birthing scene, which included a limbless baby dummy — covered in tracking dots — for performers to hold. Clare-Hope Ashitey reclined on a slant board positioned through a hole in a mattress on the floor of the elevated hotel room set built at Pinewood Studios. Dudman's team affixed a prosthetic lower abdomen to the actress — with her real legs attached to and motivating her puppet legs above — and then ejected the newborn baby dummy through an opening beneath the set. Framestore CFC then generated digital effects that gave life to the infant and allowed Cuarón to cover the scene in what appeared to be an uninterrupted three-and-a-half-minute shot, following Kee and Theo into the room, dispatching a pesky landlady and her small dog, and then ending with the birth.

Emmanuel Lubezki covered the action with a handheld camera while the landlady, then Theo, carried a lamp as the scene's sole light source. Framestore CFC performed a lidar scan of the room for tracking purposes, and digitally removed a power cable trailing from the lamp. To enable Nick Dudman and his team to insert Ashitey into the birthing rig midway through the scene, the filmmakers designed a digital transition as Theo herded the landlady out of the room and the camera tilted down to see the landlady's dog scuttle out the door. The camera then cut and Cuarón resumed action with a matching composition of Theo closing the door before returning to Kee in

position on the mattress. “The camera operator did a superb job of following the complicated choreography,” said Framestore CFC visual effects supervisor Tim Webber, “but the transition was tricky because the framing at the door didn’t line up perfectly. We did a little pseudo-3D manipulation to different parts of the frame at different times. We had to match the timing of the door closing, which was different in each shot. We also did a morph between the takes on Theo’s coat and the movement of his leg. We remapped the floorboards, projecting them onto a 3D surface, and changed the angle of the surface so that the angles lined up. It was a mixture of techniques.”

The second part of the shot had Theo returning to the mattress bed to guide Kee through her labor and deliver her baby. *In* creating the tiny child that emerges into his hands, Framestore CFC conducted extensive research and consulted with a midwife to ensure biological accuracy. “It was supposed to be a mixed-race baby,” explained Webber, “and we were lucky enough to find a great piece of footage of a mixed-race birth. Plus, I had recently had a baby, which was useful. *In* our research, we discovered that strange things happen to the color of a newborn baby’s skin. Even with dark-skinned babies, the skin starts off very light, then darkens quite quickly. And babies quite often come out blue because of lack of oxygen. We simulated that to a certain extent; but if we had emulated the footage too closely, it would have looked less real to people who might not be familiar with what happens during birth.”

Framestore CFC modelers Alessandro Bonora and Ben Lambert crafted the digital model, and then CG supervisor Andy Kind and rigger Felix Balbas led development of muscle and skin simulation, working closely with animation supervisor Michael Eames. “A baby’s skin is actually quite floppy when the baby first comes out,” Webber observed. “The skin is so loose it bunches up a lot when it’s held. We did a fair amount of work on skin-deforming techniques to get good wrinkles, and we used our muscle system with muscle dynamics to give it some wobble.” 3D roto-animation of Clive Owen’s hands drove contact points with the baby model, producing wrinkle deformations via keyframe control. “Animator Craig Bardsley spent a long time animating the birth; and he did it beautifully in his first take. The baby appeared to be lifeless when it first came out, and then she jolted awake. Alfonso asked us to push that further, increasing the suspense of: ‘Is it alive?’”

Digital artists used subsurface scattering and global illumination to create delicate translucency with layers of mucous, sticky tufts of hair and a subtle darkening of the skin as the infant drew its first breaths. Framestore CFC compositing supervisor Ivan Moran’s team blended elements into the shot with an animated umbilical cord, matched to the practical umbilical attached to the prosthetic. Paul Corbould’s team provided a gush of fluid at the prosthetic exit point, and — to simulate freezing temperature in the room — created effects of breath fogging and backlit vapor rising from the infant’s skin. “The special effects guys chopped the arms and legs off a doll, cut it open and had steam coming



Theo visits the Ministry of Art, a fortified repository of world art treasures situated inside the former Battersea Power Station. Production shot an establishing view of the structure with the camera pointing south across the River Thames. Double Negative added a bridge spanning the river, digitally removed contemporary waterfront buildings, and modified power station architecture with new windows, roof extensions and modern art sculptures – including a 40-foot balloon pig, resembling the iconic

out. We carefully patched in those steam elements to match the baby's movement. We also simulated some swirling steam for when the baby's arms waved around."

For shots of the baby peeping from blankets in its mother's arms in subsequent scenes, Nick Dudman's team provided an animatronic puppet, which Framestore CFC replaced in all but a few fleeting wide shots. "The look of the baby changed a lot after they built the practical puppet," explained Webber.

"Alfonso asked us to create a much smaller baby in our birth scene, which didn't match the puppet, so we ended up generating 20 baby shots." The digital baby is seen in a brief, happy moment lying on a bed where sympathetic 'fugees' give Theo and Kee refuge. "Alfonso shot the bedroom scene with the puppet. We had to do quite a lot of work painting out the animatronic because of the disparity in size. Then we replaced it with our CG baby, interacting with the bed and reacting to the touch of its mother's hands."

The idyllic scene is interrupted as rebels break into the fugee camp, abduct Kee and her child and engage government troops in vicious gunplay. Cuarón filmed the abduction on location at Bushey Hall in Hertfordshire. Double Negative created digital set enhancements, extending walls, adding barbed wire fences and occasionally eliminating neighboring suburban homes. Corbould's team provided pyrotechnic elements, shooting all of the bullet hits at Pinewood, which Double Negative then added digitally.

Theo chases Kee and her captors into an even fiercer conflict in an adjoining street, filmed at a disused Royal Air Force base at Upper Heyford in Oxfordshire. In the film's longest unbroken cut, Theo takes cover from gunfire, filmed in Bushey Hall, and then proceeds to run into the Upper Heyford battle zone toward a bombed-out apartment block where Kee has been taken. He enters the crumbling edifice, ascends several flights of stairs, finds and rescues Kee, and makes his way back down and outside again — all amidst a full-scale military assault.

"The camera panned onto greenscreen from the Bushey Hall location," related Frazer Churchill. "We did our transition at the corner of the building as the camera became Theo's POV. Again, we were following Alfonso's motif for invisible transitions. There was good motivation for the camera move, because Theo had stopped to catch a moment's breath, and then he peered forward into where he

cover image from Pink Floyd's classic *Animals* album, to shoot the foreground element of Theo's chauffeur, driven by Bentley approaching the Ministry building, Double Negative visual effects supervisor Frazer Churchill selected a motorway bridge that was long enough to appear to span the River Thames, and production dressed it with military hardware. Churchill lined up the shot using digital playback of the Battersea plate to create a temporary composite. Double Negative blended the foreground element with matte painting enhancements and the main production plate, which included a flight of birds appearing to pass under the bridge.



Cuarón staged an attack on a van carrying Theo, his ex-wife Julian, and three other passengers, in a shot that ran more than four minutes. The production filmed the scene on location in the English countryside using a custom-built camera-car rig, resembling a motorized four-wheeled flatbed, that enabled a roving camera to protrude through the vehicle's roof to shoot inside. Double Negative blended six live-action segments with complex digital transitions to create the impression of a single seamless shot.

was about to run. The audience didn't feel any 'cheat' had happened as we panned away from Clive, because the frame was full of information. Clive ran back into shot in the second location, which we shot two weeks later." Churchill and Double Negative visual effects producer Rupert Porter used witness cameras to record camera moves and guide continuity from one transition to the next. "When Alfonso said 'cut,' my team ran in, measured where the camera operator's feet were, took pictures of where he was and videotaped his movements. We were very reliant on the camera operator's muscular memory, but the witness cameras were helpful in determining reference positions for the next portion of the move."



Julian's death in the van attack galvanizes Theo to help Kee (Clare-Hope Ashitey), a pregnant fugitive from the law. Hiding out in a refugee camp, Kee gives birth in a derelict hotel room. Animatronic supervisor Nick Dudman created a birthing rig that included a limbless baby dummy, covered in tracking dots, for the performers to hold.

Double Negative sequence lead Jolene McCaffrey digitally enhanced the Upper Heyford location, tracking in a fourth floor to a three-story barrack dressed to represent the wrecked 'Pierpoint Tower' apartment complex. Before pursuing Kee's abductors into the building, Theo dodges gunfire by running through an abandoned bus being used as a home by fugees. The complex choreography — in and out of the bus, then across the battlefield in one take — was further complicated when a pyrotechnic squib exploded fake blood across the camera lens. "It was completely accidental," recalled Churchill. "A fugee extra in the bus was off her mark. She turned to camera and splashed the lens. We continued with the take because daylight was fading fast, and there were so many elements going on it was impossible to communicate the 'cut' to everybody." After rapid evaluation of the problem on set, Churchill worked with Double Negative to incorporate the blood splash into the scene through a transition into the Pierpoint building. "The shot continued from Upper Heyford into a studio interior; so we not only had to remove the blood — which was much more than is visible in the film — we had to add blood to make it bridge the transition. 2D artist Niki Wakefield spent a lot of time removing and replacing blood so we could believably animate the drops to thin and roll away as the camera moved around."

The Pinewood Pierpoint set consisted of two floors that the production redressed to represent three. Cuarón covered the action in a series of interlocking handheld moves, chasing Owen up a flight of stairs, panning and transitioning to create the impression of Theo's relentless, desperate ascent. Double Negative integrated bullet hits, muzzle flashes and flying dust throughout the scene, and generated views beyond a blown-out exterior wall where Theo finds Kee hunkered with her child. The production placed a greenscreen beyond the Pinewood set into which compositors tracked a cyclorama of a tank, filmed from a high angle in Upper Heyford, and elements of a location in Woolwich with matte-painted features of Bexhill.

Clare-Hope Ashitey carried the animatronic baby in a bundle during the scene. Compositors inserted glimpses of the CG infant into the actress's arms and built up the shawl using 2D projection techniques and hand-painted detail. The shot then followed Theo and Kee back down the stairs and outside to Upper Heyford, concluding more than eight minutes of unbroken screen time containing six seamless digital transitions. In a separate cut, a bazooka blast



Framestore CFC – under visual effects supervisor Tim Webber – digitally painted out the dummy and substituted a CG model of a mixed-race female child, complete with skin that deformed and reacted to 3D rotomation of Clive Owen's hands.



from the Pierrepont Tower triggers a firestorm of gunfire, the majority of which Paul Corbould's team created at Pinewood as full-scale pyrotechnic elements that Double Negative tracked into the scene.

Theo's journey ends as he assists Kee and her child, escaping into the English Channel in a rowboat, filmed in part on a Pinewood water tank surrounded by gray backing. Paul Corbould's team pumped the set with fog and Double Negative extended the environment with plates of Chatham seafront

extended with a digital matte painting. The production shot wider shots of the rowboat on location off the southwest coast of England, in Portland Bill, a natural harbor that contained fog pumped at high volume from a small fleet of boats. Framestore CFC composited the CG baby into shots of Kee burping the prosthetic infant, and Double Negative added further veils of mist. For the film's final moments, as a ship named the Tomorrow appears out of the gloom to rescue Kee and child, the production photographed a full-scale vessel in open water, which Double Negative layered behind fog.

"This film was about hope," said Frazer Churchill. "I think it was an important film that said a lot about our world, who we are and where we're going; but ultimately it was a positive message. I consider it a privilege to have worked on such a powerful and unique film, where visual effects were so well integrated into the story. Alfonso understood the possibilities of what he could achieve with visual effects. They were simply there to enable his vision."

Children of Men photographs copyright © 2006 by Universal Pictures. All rights reserved. Production still photography by Jaap Buitendijk. Special thanks to Aisling O'Brien, Steph Bruning, Bette Einbinder and Chante Hardesty.

Kee cradles her newborn in the ruins of a bombed-out apartment building. Cuarón shot the scene as part of a sequence filmed on locations in southern England and at Pinewood Studios. In another seemingly unbroken shot, the camera follows Theo through the refugee camp as he dodges gunfire and then searches the ruined building for Kee. Nick Dudman's team provided Clare-Hope Ashitey with an animatronic baby to hold. In postproduction, Framestore CFC digitally replaced the infant's face with its emotive CG creation. Double Negative added bullet hits and pyrotechnics, and generated digital transitions that blended six takes of nonstop action into a single shot more than eight minutes long.

John Sullivan on Next

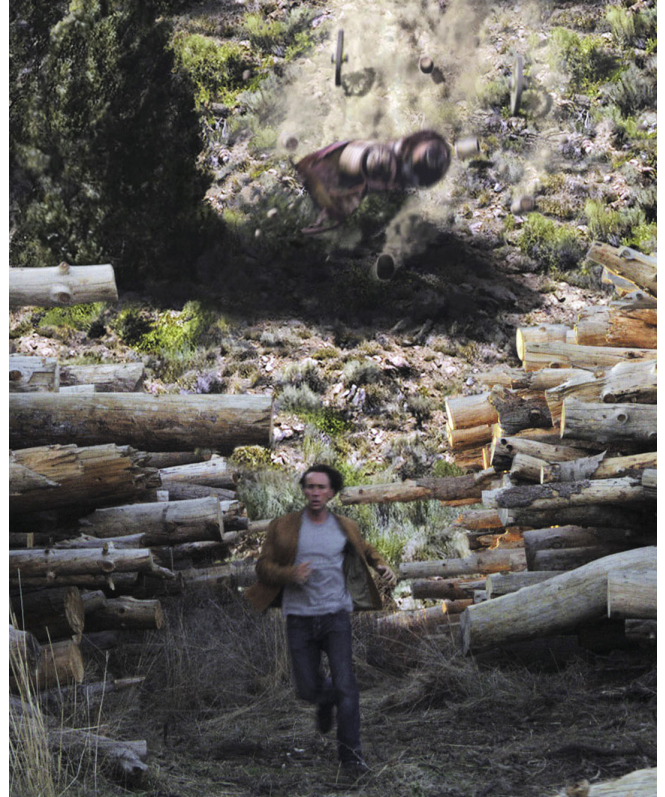
Article by Jody Duncan

Science fiction stories and novels by the late Philip K. Dick have been providing grist for the movie-making mill ever since *Blade Runner* — an adaptation of Dick's *Do Androids Dream of Electric Sheep?* — burst onto movie screens in 1982. Over the next two decades, the author's work served as inspiration for *Total Recall*, *Screamers*, *Imposter*, *Minority Report*, *Paycheck* and *A Scanner Darkly*.

For *Next*, a Revolution Studios picture directed by Lee Tamahori, screenwriter Gary Goldman — who also penned *Minority Report* and served as its executive producer — and co-writers Jonathan Hensleigh and Paul Bernbaum again dipped into the well of Dick's imagination, updating the author's futuristic *The Golden Man* to a present-day narrative. *Next* involves Las Vegas mentalist Cris Johnson (Nicolas Cage), whose cheap theatrics disguise an uncanny extrasensory power that is both a gift and a burden: the ability to see a few minutes into his own future. When Los Angeles is threatened with a nuclear terrorist attack of massive proportions, FBI counter-terror agent Callie Ferris (Julianne Moore) demands that Cris use his talent to thwart the coming catastrophe. Wary of becoming the resident rat in a government science lab, Cris refuses — until the terrorists kidnap his future, a lovely schoolteacher named Liz Cooper (Jessica Biel).

Goldman conceived the idea of adapting *The Golden Man* into a screenplay when he was interviewed by Jason Koornick, webmaster of the Philip K. Dick website, who had been given an option on one of the author's short stories. The two men formed a partnership, and *Next* was born.

Throughout the production's development and preproduction phases, Lee Tamahori — who intended *Next* to be primarily an in-camera, physical-effects-driven show — saw digital effects as playing a minor role. As a result, visual effects supervisor John Sullivan joined the production just four weeks prior to the start of principal photography. The digital effects shot count grew from a mere handful to more than 300 shots in the course of production — still a relatively modest number, but ambitious given the show's painfully brief postproduction period. "We started on the show in April of last year," explained Sullivan, "and the original intent was that we deliver in November of that same year. That was asking for a lot, which became clear as we got more into the CG effects." Though the delivery date was ultimately pushed back, Sullivan and visual effects



producer David Moulder were only able to meet it — and stay within budget — by dividing the work among seven visual effects vendors: Digital Dream, Digiscope, Look! Effects, Comen Visual Effects, Tweak Films, Pixel Magic and Pacific Title & Art Studio. Sullivan also hired two freelance composers, Tim Carras and Joseph Bailey, to work with him on the production side.

Next opens in Las Vegas, where low-profile magician Frank Cadillac — aka Cris Johnson — supplements his meager earnings by playing blackjack at a Vegas Strip casino. Production shot interiors and exteriors at the Morongo Casino in Cabazon, a small desert community people pass on their way to Palm Springs — a few stopping just long enough to explore the full-scale brachiosaur sculpture that stands, improbably, at the side of the road. Sullivan shot stills and moving plates in Las Vegas, to be used as backgrounds for the Cabazon footage. “In Cabazon, we mostly shot right around the casino, knowing we were going to have to put Las Vegas in the background. *I* went to Vegas later on in the show, when we knew for sure which of the Cabazon shots we were using. *I* shot motion plates there with a Panasonic HD camera. *I* also shot quite a few tiles using my Canon still camera. We picked what worked for each particular shot, and put it in the appropriate background. Fortunately, they were all night shots. Greenscreen would have been nice in some places — but the black was pretty forgiving. We tracked and rotoed things as needed, and put in these pan-and-tile backgrounds.”

Pursued by Las Vegas police after a shooting incident in the casino, Cris steals a silver Dodge Charger and races through the city streets, finally losing the cops by gunning the car over a flashing railroad crossing. Using his precognitive abilities to ascertain the outcome if he drives 80-some miles per hour, Cris sees the oncoming train hitting his car, obliterating it into thousands of pieces. A quick rewind — a ‘snapback’ to 30 seconds earlier — finds Cris correcting his miscalculation, flooring the accelerator to well past 100 miles per hour, and successfully crossing the tracks just inches ahead of the train.

Digital Dream, with Jerry Pooler supervising, created much of the train and car sequence digitally. “At a location in Fillmore, we shot plates of a car driving up to the tracks and driving away from the tracks on the other side. But we couldn’t do this stunt with the car and a fast train right in the middle of Fillmore; and so we decided to create a CG train for that sequence, as well as a CG Charger.” Visual effects also replaced the location in one direction, as it was visually uninteresting and had served as the parking area for the production. “We shot a lot of motion reference on location, utilizing the Panavision Genesis camera, so we could see what it would look like had it been shot with that camera. And then we shot digital stills using an 11-megapixel Canon camera, allowing us to create a high-resolution tiled background, matching to that moving reference.”

The snapback effect — in which Cris ‘sees’ two minutes into the future, and then snaps back to real time — recurs throughout the film. “Lee did not want to make these flashbacks big visual effects shots. And he didn’t want to do it exactly the same way each time. An effect is interesting the first time you see it; but it is less so each subsequent time you see it. So it wasn’t one signature effect that was used every time there was a flashback scene. Lee mixed it up, and had the effect evolve as the movie went on.

“For some shots, we put a greenscreen behind Nic Cage and did a move on him; and then we would do a separate move on the background, so there was a different sense of motion blur going on. *In*

other shots, you actually see him splitting off from himself, doing different things as a result of his having seen the consequences of his first action. *In* those cases, we'd shoot him performing the scene; then we'd go back and start the action again, this time with Nic changing his performance and action in some way. Sometimes we shot him multiple times with a stationary camera; other times, we shot him multiple times using motion control so he could walk different paths, and all the different Cris Johnsons would intersect and criss-cross through the same spot. Throughout the movie, we tried to avoid repetition in the flashback effect; and, even if we did the effect in a similar way to another shot, we treated it a bit differently."

Nicolas Cage's considerable previous experience in visual effects films helped him to maintain performance continuity through the many multiple passes. "It was a difficult thing to ask of an actor. 'Okay, we need you to walk through this spot on the moving shot, and make your turn exactly this way, at exactly this point.' Because we were dealing with motion control, we were tied to precise time-lines. The walking through and the point of transition couldn't be changed. *If* he was off, we could roto him and shift his position a bit — but we didn't want to have to do that. So we really tried to get the timings right. Lee had to give Nic exactly the right direction, down to what his body was doing precisely at the moment he was making the turn. *It* took us a number of times, using video splitters and stuff like that, to get the performance we needed; but, throughout, Nic was great about it all. No matter what we asked of him, he was unfazed by it."



Next – based on a story by Philip K. Dick – involves a Las Vegas magician, Cris Johnson (Nicolas Cage), who possesses the supernatural ability to see a few minutes into his own future. Fleeing FBI agents who plan to exploit his powers to thwart a cataclysmic terrorist attack, Johnson leaps off the side of a cliff and 'surfs' the steep slope to the bottom of the mountain, chased by a landslide of dislodged logs and industrial equipment. Director Lee Tamahori realized the extended 'avalanche' sequence by integrating practical and digital effects with live-action plates of Cage running down mountain-area inclines.

As he has foreseen in a vision, Cris meets Liz at a Vegas diner, then hitches a ride with her to Flagstaff when his car is stolen. On the way, they stop at the ‘Cliffhanger Motel’ — a structure that, as its name suggests, sits precariously at the edge of a steep cliffside. Production designer William Sandell added facades to a similarly situated restaurant near Lake Arrowhead to create the motel. Their cabin surrounded by Ferris and her SWAT team, Cris and Liz escape — the former by jumping off the side of the cliff, and charging down the steep slope like a snowboarder; the latter by driving her Toyota Land Cruiser into a fenced area holding early-20th-century industrial relics, and jumping out at the last moment as the vehicle, fence, and antique wagon full of logs topple over the cliff, creating an avalanche of debris that chases Cris to the bottom of the mountain.



Visual effects supervisor John Sullivan oversaw the show’s 300-plus effects shots, which were divided among seven visual effects vendors. For a shot at the end of the avalanche sequence, in which a tumbling log flips a car left on the road by FBI agent Callie Ferris (Julianne Moore), visual effects artists composited a hydraulic car-flip gag — executed by special effects supervisor Clay Pinney and his team — with location footage of Cage and Moore. Digital artists also painted out the hydraulic rig and added CG logs, debris and dust to the shot.

Tamahori and the production team realized the key action sequence through a combination of practical effects by special effects supervisor Clay Pinney and digital effects. “Clay Pinney really did roll the Land Cruiser over the cliff. In fact, in one rehearsal take, it went way down the cliff. The location also had been dressed with a water tower and barrels and the wagon with logs on it. Clay and his boys did a beautiful job of rolling all that stuff over the cliff using cable pulls to tie everything together.”

Initially, the filmmakers had planned to use a Cablecam system to shoot motion control plates of Nic Cage slipping and sliding down various slopes near Arrowhead and Big Bear, and then replay the moves to capture a separate pass of the practical logs and debris rolling down the same declines. “We had worked out with the Cablecam guys a way of shooting this remotely, through radio controls, which would allow us to shoot a lot of practical rocks and logs rolling down the mountain, instead of having to do it all with CG. We knew that this cable system would never be 100 percent registered; but close enough that we could pull the passes together. We tested it beforehand, and it worked great. But the moment we got up there and started shooting, we had terrible problems with the radio control. We were too close to some radio towers, and they kept crushing the signal — and so it didn’t work at all.” As a result, that part of the avalanche sequence featured no moving camera multiple-pass shots. “Without the option of moving multiple passes, most of the shots were lock-offs, a stuntman running with some debris behind him, or shots of Nic with a lot of CG objects put in. So, for example, for a shot of the car rolling behind Nic as he runs down the hill, we shot a lock-off of Nic running down the hill and a lock-off of the car rolling down the hill; and then we had to roto them together.” A team at Pixel Magic, under visual effects supervisor Victor DiMichina, executed the rotoscope composite of the two-element shot, which also required digital artists to paint out ropes on the moving vehicle.

As finally put together, the avalanche sequence required so much digital augmentation that Sullivan divided the shots among several facilities, in addition to Pixel Magic. Digital Dream added to the action with an animated CG Land Cruiser that flew over Nicolas Cage. At Digiscope, supervisor Dion Hatch and his team added rocks and wagon wheels and other debris to mountain plates. Under the direction of Max Ivins, Look! Effects added a traction engine tumbling down the hill, dislodging CG logs that hit an FBI vehicle, causing it to flip into the air. “We shot multiple passes of the car flip with motion control and with a locked-off camera to get the elements that we needed to make the shot work. Clay Pinney and his guys did a hydraulic flip on the car at the location; and then Look doctored up the shot, painted out the hydraulic rig, and integrated the car into the environment.”

For shots after the avalanche has stopped, featuring debris and logs gathered at the bottom of the hill, Josh Comen at Comen Visual Effects applied textures to some of the real logs used in the live-action. “The set-dressing logs looked fake — very polished and clean, like logs out of Bear Country Jamboree! So we had Comen re-texture all the logs using textures developed by Look. When it was all put together, the entire sequence looked great.”

The chase ends with Cris’ being apprehended by Ferris, and Liz’ being captured by the terrorists. When Cris has a vision of Liz strapped to a chair on a Los Angeles rooftop, wearing a suicide vest packed with explosives, he helps the counter-terror unit in tracking the terrorists to a warehouse compound on a Port of Los Angeles pier, where weapons of mass destruction are being unloaded from a cargo ship. Production filmed the pier action in the Long Beach harbor, where a real cargo ship was berthed. The cargo ship is the setting for the film’s most extensive, and final ‘snapback’ visual effects sequence, which features many Cris Johnsons splitting off in multiple directions as he attempts to out-manuever the terrorists. “This sequence, in which



After a precognitive vision reveals the woman he loves being slain by the terrorists, Johnson joins the counter-terror team. To illustrate Johnson’s fast-forward glimpses into the future to test evasive maneuvers in the face of terrorist gunfire in the hold of a cargo ship, the filmmakers devised shots in which multiple Cris Johnsons, each executing a slightly different action, fade in and out of the scene. Crews shot multiple motion control greenscreen passes on Nicolas Cage, who altered his performance with each take. Visual effects artists then integrated the greenscreen elements into plates shot on location at a Long Beach pier.



The film appears to end with the terrorists detonating a nuclear bomb in Los Angeles. Seeking to avoid the standard wide view of a mushroom cloud emanating waves of destruction, Tamahori instead conceived a shot that remained tight on the main characters within the ship, bathed in the intense flash of the nuclear explosion. Visual effects artists enhanced practical lighting digitally, and added a burn effect to Cris’ jacket to suggest the heat from the blast.

we see many versions of Cris trying out different tactics, was the culmination of all our R&D for the flashback effect.”

The filmmakers shot the background plate at a practical location, then utilized motion control to shoot Cage on stage against greenscreen, performing all of the various actions featured in the sequence. “When we were shooting it, we asked Nic to do 15-plus different things — falling one time, dodging one time, doing something else the next take, something else the next. We weren’t sure how it would all come together; but we knew that having as many options as possible was going to be helpful. Lee and editor Chris Wagner had all of these performance elements to choose from; and then we went from there, massaging those different actions together in the sequence.” Initially, the sequence featured as many as 40 Nicolas Cages; but that number was trimmed to clarify the action. “The different Nics come in and then fade out when their time expires. We used fades, roto, white highlight flashes, distortion plug-ins — we used just about everything to add variety and visual excitement to these shots.”

After rescuing Liz through his videogame-like maneuvers, Cris precogs the nuclear bomb detonating in Los Angeles. “Because there have been so many movies with nuclear explosions, Lee wanted to avoid the cliché of the circular impact wave coming out and a mushroom cloud rising up in the background. So one of our early ideas was to do something very simple — like hitting the actors with Ritter fans, and then going to white — because this is actually a transition to a much earlier time-frame. At this point in the film, we realize that all of this has been Cris’ look into the future, and that none of it has really happened yet. So Lee was going to do this simple sleight-of-hand gag to make that transition.”

Further discussion led to a more dramatic effect — but still a deviation from the customary wide shot of shockwaves emanating out, destroying everything in their path. “One of the ideas was to do a stationary camera shot of the ship, and show it flipping over in the blast. We animated that in our initial previz — but it looked wrong, dynamically. It just looked like a toothpick flipping over. Finally, Lee decided to have the ship break in half, with a big chunk of it rising up and sliding along the dock, with a very bright flash in the background, and fiery balls flying at us to suggest the explosion.”

Visual effects artists at Tweak Films, under the supervision of Scott Liedtka, built a CG ship based on an Eyetroneics scan of the real ship in the Long Beach harbor, and created its destruction and move on a CG dock utilizing Maya, proprietary destruction and water software, as well as Shake for the compositing. For one cut in the sequence, Pacific Title & Art Studio, with David Sosalla supervising, added a digital burn effect on Nicolas Cage to suggest the heat from the blast.



A wide view showed the cargo vessel battered by the nuclear shockwave, with large chunks of it crashing onto the adjacent dock. Visual effects artists built a CG vessel from a scan of the real ship filmed in Long Beach harbor, and employed Maya and proprietary software to simulate its destruction and impact with a CG dock. In a denouement, the catastrophic event is revealed to be another of Cris Johnson’s visions – one he is able to alter.

Forewarned with knowledge of this potential apocalyptic event, Cris, back in current time, takes steps to alter the future — bringing the film to a happy close. By the time John Sullivan's effects assignment came to a close, he and his teams had produced more than 300 effects shots on a very short schedule — a feat that was accomplished only because of the cooperation of various houses working simultaneously on the project. "As a visual effects supervisor, I've always preferred to work with a number of effects houses. I find that it gives me a lot more flexibility. When we get to the end of the job and the producers want to insert a whole new sequence or a bunch of visual effects shots, I can do that, because I have several facilities at my disposal. I don't have just one house that is totally backed to the wall with its workload and schedule. The multiple-house approach really came through for me on this show."

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Eric Durst & Stu Maschwitz

The Last Mizmy

Article by Estelle Shay

New Line Cinema founder and co-chairman Robert Shaye has made a name for himself as a maverick who took a small company specializing in the distribution of art-house films and grew it into an industry powerhouse. Never one to shy away from challenges, Shaye had even tried his hand at directing back in 1990 with the film *Book of Love*. For his newest undertaking, *The Last Mimzy*, Shaye once again assumes the role of director, determined to bring a favorite story to the screen fueled by his own unique vision.

Based on a 1943 short story “All Mimsy Were the Borogroves,” by Henry Kuttner and C. L. Moore, published under the pseudonym Lewis Padgett, the property had caught Shaye’s eye more than ten years ago, when producer Michael Phillips first brought it to him. “It was a story that Bob had read when he was a kid,” stated visual effects supervisor Eric Durst, “one that had really enthralled him.”

Durst, too, was drawn to the tale of two young siblings, vacationing with their parents at an island retreat off the Washington coast, who discover a strange box washed up on the beach. *Inside* it are several mysterious ‘toys’ that cause the children to undergo a powerful mind expansion, eventually learning the true nature of their discovery and fulfilling their destiny as saviors of a decaying human race of the future.

In addition to its technical challenges, Durst saw in the story a rare opportunity for considerable design input. “The script had a lot of great visuals, and I liked the idea that there was the potential for creative approaches to some very subjective concepts. One thing both Bob and I felt very strongly about was that the effects had to be photoreal, even if the things that we were depicting were things that don’t happen in real life. We wanted to work off the premise that if they did happen, and they were photographed — this is what they would look like. We also wanted a level of subtlety in the imagery, so that it didn’t overpower the story or the children’s performances.”

Durst and visual effects producer Mark Soper, preferring to keep most of the visual effects involving the toys under one roof, assigned 237 shots comprising the bulk of the work to *The Orphanage*, under visual effects supervisor Stu Maschwitz. “Those shots were really tied together conceptually, and we knew the design of them would set up a lot of the precedent for everything else in the film,” said Durst. “*The Orphanage* had good access to Houdini, which was the right tool for the type of imagery



we had in mind and for doing procedural animation, which we knew would be an important component of those shots.”

Non-toy-related effects encompassing another 98 shots were distributed among nine supporting vendors, including Giant Killer Robots, Rising Sun Pictures, EdenFX, Technicolor Toronto, Amoeba Proteus, Tweak Films, Digital Backlot, Amalgamated Pixels and Fidi FX. “Though this was not a 1,000-shot show,” said Durst, “the sheer design of it, figuring it all out and getting it to work was a big deal, and I wanted to make sure our pipeline stayed clean. By distributing the work to enough vendors so that we could multi-task, things tended not to get bogged down.”

The container and its contents are revealed early in the story as Noah (Chris O’Neil) and his little sister Emma (Rhiannon Leigh Wryn) pull the mysterious box from the water. Practical props built primarily for use as placeholders during filming were laser-scanned by Gentle Giant Studios and delivered to *The Orphanage*. For shots of the container, a geodesic box with chambers that slide open, unbidden, to reveal hidden recesses, *The Orphanage* wound up replacing the real prop with its CG version in nearly every sequence. “There’s one shot of the kids opening it on the beach,” stated Stu Maschwitz, “where the box is literally less than an inch away from the camera lens. They’d shot the kids with a Frasier lens system — a snorkel lens that has near-infinite depth of field. So we had to put our CG box into these shots that had this unique lens characteristic to them, and we couldn’t hide behind the kind of shallow depth of field you’d normally get when putting something that close to the camera.”

At home in her bedroom, Emma discovers the container’s most precious cargo, a floppy-eared stuffed rabbit — Mimzy — that utters sounds only she seems to understand. Durst debated whether or not to supplement Mimzy’s vocalizations with movement and expression. “We decided that Mimzy should not be animated, even in subtle ways,” remarked Durst. “We felt that if we started to animate her, then she would become a character in the film, and she really wasn’t that. We wanted Emma to relate to her just as any kid would to a stuffed animal.”

Among the other objects revealed are rock shards that Mimzy prompts Emma to spin, like a top, causing them to float above the ground in a whirl of revolving motion. Maschwitz and his crew captured HDR reference on the set, where real spinners were hung from motorized rigs by the practical effects team. “Though you never see our CG spinners that closely,” observed Maschwitz, “we rendered them with full ray-tracing and subsurface scattering, and with crazy motion blur samples so that we could actually capture all the intra-frame motion blur that happens when something is spinning that fast. The practical props provided great reference, and I think there’s at least one shot in the film where there’s a mix of practical spinners hanging from wires that we painted out and CG spinners spinning right next to them.”

When all the spinners are in motion, the children watch in awe as colorful energy strands form around the shards, merging to create a cocoon-like force field. Exploring concepts for the cocoon, Durst began with rough animatics provided by *Image Engine* in Vancouver. “We knew the cocoon was going to be a round or oval object, sort of like a capsule,” related Durst, “because at the end of the movie it becomes part of a big time-travel machine that takes Mimzy back to the future. I also wanted the design of it to be very organic, and to harken back to the geodesic look of the container — so that was our starting point.”

Working in *Houdini* and rendering in *Mantra*, *The Orphanage* sought imagery that was more than just the typical magical glow effect. “The idea is that these kids are tapping into this deeper structure of the universe,” explained Maschwitz, “which is an easy thing to say, but hard to turn into something concrete. That’s where CG supervisor Matt Hendershot really shined, because he has the unique ability to create art with math. There’s this highly complex logic that’s driving the way any one strand of energy flows from a spinner up into the cocoon — and you can trace it. It’s like a 3D spirograph. Plus, the incredibly dense network of instructions for creating this thing could be manipulated in real time; so Eric could sit over Matt’s shoulder and say: ‘It looks too structured. I need it to look more organic.’ And that was just a slider move away.”

Emma reaches out to touch the cocoon. As her finger penetrates the force field’s sphere of influence, it breaks into millions of moving particles that rematerialize into a solid digit as soon as she withdraws her hand. Shaye and Durst sought a look for the granulation effect — featured in several other sequences, including one in which Emma inserts her entire face into the cocoon — that was somewhat photoreal, but would also be gentle and non-threatening. Artists began by working with 3D laser scans of Rhiannon Leigh Wryn’s hands and face, captured on set by *Eyetrionics*, a scanning company known for its highly mobile systems and expertise in people-scanning. A particle system that could be operated in real time via sliders was devised to manipulate the imagery. “Every particle was a piece of geometry that was rendered fairly realistically,” said Maschwitz. “They cast shadows, they did



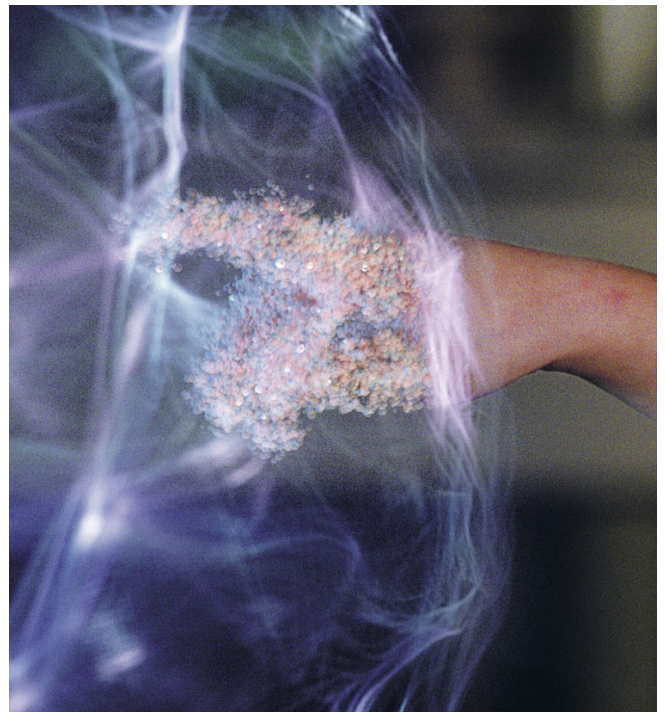
In The Last Mimzy, siblings Emma (Rhiannon Leigh Wryn) and Noah (Chris O’Neil) discover a mysterious geodesic box that washes up on a beach and opens to reveal a number of seemingly innocuous ‘toys’ – among them a floppy-eared stuffed rabbit named Mimzy. New Line Cinema founder Robert Shaye helmed the project, calling upon support from visual effects supervisor Eric Durst who turned to The Orphanage and a coterie of supporting vendors for help in realizing the tale’s fanciful elements.



Having secretly stashed the container under a bed at home, Noah and Emma are astonished to find that when rock shards from the container are spun like toy tops, they put forth energy strands that join to create a cocoon-like force field. Responsible for most of the toy-related effects – including the spinners and the cocoon – The Orphanage relied on Houdini to achieve the desired organic look for the cocoon, constructed much like a 3D spirograph to suggest a mathematical logic behind the flowing strands of energy.

subsurface scattering and all that sort of thing, which meant that if we made them too dense, it was too much like an actual object squirming and writhing. There were takes of Emma putting her face in the cocoon that were just horrific. It looked like she was putting her face into a meat grinder! So we were always walking this fine line, trying to find the right balance.”

Noah is drawn to another object in the found container, a crystalline card with shimmery patterns inside it that seem to react to his thoughts. On set, the card was represented by various props, including ones with lines etched into them and wired with LEDs and others that were clear with just a few tiny tracking markers. Orphanage artists used Houdini to animate the crystalline fractures moving inside the card, and Brazil 2 for ray-traced renderings. “We viewed it as a kind of Rubik’s Cube that Noah is trying to solve with his mind,” said Maschwitz. “We looked at a lot of photographic reference of fissures and cracks in geological formations to understand what makes a crystal look like a crystal, since all of these things follow sets of rules that we don’t really think about. There’s a reason that veins on a leaf of a tree look exactly like the branches of the tree, which look exactly like the roots of the tree; and we were trying to tap into that sense of a collective unconscious. Our Houdini artists would create these same kinds of rules for our crystals. We thought that would help make it believable that Noah could be transfixed by this thing.”



When a curious Emma inserts her hand inside the cocoon, the appendage appears to dematerialize, breaking into millions of tiny glowing granules. Working from an Eyetrionics 3D laser scan of the young actress, Orphanage artists achieved the granulation effect – an artful balance between photoreal and magical – using a particle system that could be manipulated in real time.

Noah discovers that when the shifting fractures lock into a certain pattern, an entirely new way of looking at the world around him opens up. “The script referred to everything as being hyper-real or hyper in-focus,” remarked Durst, “but we tried a number of versions of that, and none felt right. Then we began exploring the idea of everything being seen through this prism of crystalline optics, tying it into the card in terms of its influencing what Noah perceives.”

Orphanage artists manipulated the live-action plate photography, breaking the imagery apart in compositing and imparting a crystal-faceted prism look to suggest that, in his altered state, Noah could see and understand all the forms and patterns

inherent in nature that to the untrained eye might seem utterly random. “That was all done inside the compositing environment, in After Effects, using intersecting geometry or planes in 3D space,” explained Maschwitz. “First Eric and I would print out a shot and sit with rulers and markers, drawing lines through it trying to capture why it was beautiful. Then Steve Jaworski, our compositor, would find ways to trace the edges of those forms, using them to create little exposure events in the plate by changing the color — things like that. It was a constant challenge to our ability to do something really subtle. It challenged our color pipeline, because we needed to be able to predict what we were going to see on film, and it was hard to preview at anything other than full resolution because everything was so highly detailed. In a way, what we wound up creating inside the compositing environment was every bit as complicated as any 3D effect.”

In this powerful new state, Noah psychokinetically moves a can of Sprite, causing a wormhole to open in the air above it that sucks up the can and spits it out several feet away. The effects team gave considerable thought to the look of the wormhole, an effect first seen in an expository sequence in which a future-world scientist sends Mimzy off on her mission into the past. As with all of the effects, design considerations for the wormhole were paramount, and *The Orphanage*’s Houdini artists sought inspiration for its look in the spiral, organic shape of a conch shell — one of the objects found in the container.



Noah examines a crystal card – another of the container’s treasures – whose shimmering reflections, refractions and interior facets were created by The Orphanage.

An after-image that flashes briefly in the wake of the wormhole appears as a Tibetan mandala — a circular design thought to be a symbolic interpretation of the universe. Referenced directly in the narrative, the mandala was seen as a way to unify the movie's effects, influencing conceptual designs for the wormhole, the container, the moving patterns inside the crystal card, a force field effect created for a climactic sequence, and a final pullback shot revealing a vast meadow of flowers.

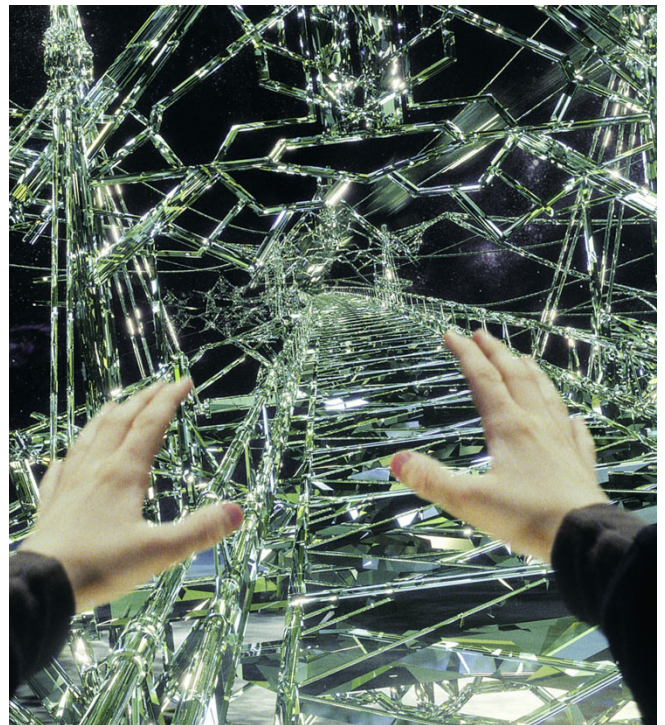
Another of Noah's newfound powers is his ability to control the web-weaving behavior of spiders using sounds he learns by listening to the conch shell. Five shots of the spiders moving under Noah's influence were accomplished with CG spiders and webs created by Rising Sun Pictures, under the direction of visual effects supervisor Tony Clark. "I had heard great things about Rising Sun and the work they did on *Charlotte's Web*," noted Durst, "so they seemed the logical choice for those shots."

The first of the shots occurs on the beach, where Noah spots a spider spinning a web and causes it to ambulate in little dance movements. Rising Sun modeled the spider and web in Maya, simulating wind in the web using layers of noise. In a later scene, Noah uses his 'spiderspeak' for a school science project, in which spiders in a terrarium, responding to sounds programmed into a computer, are seen building an elongated web in the shape of a bridge. Web interaction with the spiders was accomplished via custom deformers that could deform the webs based on the spiders' weight and stick web threads to their feet, as needed. Webs were rendered in RenderMan 3Delight using an improved *Charlotte's Web* shader.

The bridge imagery is revisited in a later sequence in which Noah dreams of building a span capable of traversing the universe. In the shot, Noah's hands are seen moving like those of an orchestra conductor as crystalline pieces of the structure fly into position to form the massive bridge in space. The effect was handled by Giant Killer Robots, under CG supervisor Greg Gladstone. "We



Noah taps into newfound powers of communication with the natural world, directing the movements of a spider he and Emma discover on the beach. CG spiders and webs for the beach sequence and for a later scene in which Noah, competing in a school science fair, demonstrates his ability to influence the webweaving behavior of arachnids in a terrarium, were the work of Rising Sun Pictures.



Noah dreams of orchestrating the construction of a web-like bridge capable of spanning the universe. Giant Killer Robots devised the effect, using Maya to fashion the crystalline structure, seen floating in space, surrounded by stars.

wanted to do a shot that was from Noah's point of view," commented Durst, "and that harkened back to the spider web bridge from the science fair. Because this time it's out in space, we get the feeling that this is some grand power that Noah is beginning to tap into — a coalescence of all the elements coming together."

Early iterations of the bridge featuring a realistic steel girder structure were abandoned in favor of a crystalline design. "It just didn't look right," recalled Durst. "*The Orphanage* was working on the crystal card at that point, and we realized that if we could make the bridge crystalline, it would tie in thematically to that. So the two companies worked together to make sure the looks were similar." Artists modeled and animated the complex crystalline structure in Maya, applying special surface shaders to provide the necessary reflective and refractive qualities.

As Noah's powers increase, so do Emma's. In a climactic nighttime sequence at the beach house, Emma saves Mimzy — and mankind — by sending her back to the future inside the cocoon formed by the spinners, this one serving as a sort of time machine powered by a generator that Noah has built. The plan nearly goes awry, however, when Emma reaches up inside the cocoon to bid Mimzy goodbye. Unable to withdraw her hand from the powered-up vessel, she is lifted off the ground, necessitating a daring rescue by Noah. The sequence, handled by *The Orphanage*, was one of the film's most ambitious.

One of the key challenges was the design and execution of the penumbra, a giant, glass-like force field that surrounds Emma as she deposits Mimzy in the cocoon. "The penumbra was in nearly every shot in that sequence," noted Maschwitz. "They were already shooting the scene, and we were still having conversations about what it should look like. I'd have my laptop with me on the set, and any free moment that I had between grabbing HDRs and shooting textures ?I was doing tests and getting feedback from Eric and Bob. It was an on-the-fly design process." As with the cocoon and the wormhole, Houdini artists created the force field as a mathematical construct, animating it with spinning triangular shapes that pincushion out from the surface of it, every so often echoing the iconic image of the mandala.

The principal challenge of *The Last Mimzy* was finding a way to translate and incorporate all of its ethereal elements into the very real story. "This film is really about the relationship between a brother and sister," concluded Durst, "and the toys are sort of the bonding element that happens to them. Though fantastical things occur, we wanted to illustrate them in a low-key enough way that they didn't undermine the real story. We didn't want to have these huge, overpowering effects that would just shut down everything else. We wanted it to play out as moments between the kids — and I think that really comes through."



In the film's climax, Noah performs a daring nighttime rescue, slipping beneath a giant impenetrable penumbra that has formed around Emma as she attempts to return Mimzy to the future, ensconced in a timetraveling cocoon. Live-action for the sequence, shot at a remote locale outside Vancouver and on a studio soundstage, was delivered to *The Orphanage*, whose artists seamlessly blended the disparate elements and added an array of digital effects that included the cocoon containing Mimzy and the giant penumbra — a Houdini mathematical construct.

ARTICLE BY JOE FORDHAM

To bring down the curtain on Walt Disney Pictures' phenomenally successful pirate trilogy, producer Jerry Bruckheimer and director Gore Verbinski decided to conclude *Pirates of the Caribbean: At World's End* with a tumultuous aquatic showdown. "From the outset, we knew that most of the third act of *Pirates 3* would be set in a giant whirlpool in the ocean," said Disney visual effects supervisor Charles Gibson. "That had been laid out early on. Industrial Light & Magic geared its research and development for our first sequel to concentrate on effects for that film, and left the maelstrom looming until we had *Pirates 2* in theaters. We had distant locations and actors common to both films, so we got shared elements out of the way by shooting parts of *Pirates 3* concurrent with *Pirates 2*. That was all in preparation for our big finale with two giant armadas facing off before a battle in a maelstrom."

The screenplay, by Ted Elliot and Terry Rossio, encompassed a variety of new locales that led to the maelstrom, beginning in Singapore, where pirate captain Barbossa (Geoffrey Rush) and Elizabeth Swann (Keira Knightley) rescue Will Turner (Orlando Bloom) from Chinese pirate captain Sao Feng (Chow Yun Fat). Guided by voodoo shaman Tia Dalma (Naomie Harris), the story then traveled to Davy Jones' Locker, mythical graveyard of souls lost at sea, where the formerly deceased Jack Sparrow (Johnny Depp) is found and rescued. Sparrow and company then join a fleet of international pirates and sail against Davy Jones (Bill Nighy), Sparrow's cursed squid-faced nemesis, who is now in league with Lord Beckett (Tom Hollander) of the East India Trading Company, threatening the extinction of all pirates.

ILM returned as main visual effects vendor on the film, building on technology that had earned the facility a long-overdue Academy Award for its work on the previous sequel, *Pirates of the Caribbean: Dead Man's Chest*. ILM's innovations included iMocap, an animation system that used on-set performances to drive highly detailed animated characters. "iMocap was the hardest part of *Pirates 2*," asserted ILM visual effects supervisor John Knoll. "It took the first half of that production to get our motion tracking working properly and our iMocap characters to behave. Each character was immensely complicated and had unique challenges, so there was never a single solution we could apply. It took about four months to complete our first multi-character shot. Once we had that working, we got much faster as we went along. On *Pirates 3*, we were able to hand Davy Jones shots to a lot of our new staff because the animation system was so well packaged."

Other key members of the ILM team returning for their third pirate adventure included animation supervisor Hal Hickel, associate animation supervisor Marc Chu and modeling lead Geoff Campbell, who further streamlined the creature animation system by refining facial shape libraries and supplied an additional ten creatures to fill out Davy Jones' crew. "It was a compressed version of our design process on *Pirates 2*," commented Hal Hickel. "We had drawings from conceptual designer Crash McCreery, Gore's storyboard artist James Byrkit and ILM art director Aaron McBride. Aaron did color renderings for our final versions. We then went straight to CG, because there was no time to

do maquettes. Geoff Campbell and his modeling crew got them built pretty fast, and creature supervisor James Tooley fine-tuned our simulation engines.”

Research and development, this time, focused on the film’s finale, in which supernatural forces cause a giant vortex to form in the sea beneath rival pirate ships. To choreograph broad strokes of the sequence, the production developed 3D previsualization with *Proof Incorporated* during production of *Dead Man’s Chest*. ILM then launched into technical development, based on its experiences with digital oceans from *A Perfect Storm* to *Poseidon*, but ran into challenges that, initially, stumped the team. “I have to admit,” confessed Knoll, “I had a naïve view of how to approach the maelstrom at the beginning of production. I imagined the storm as a giant flushing toilet bowl a mile across, with ships on either side, firing at each other. My first thought was to create a big, modeled surface of the vortex shape and then place a deep-water shader on top of that, with all its associated spray and foam. As long as we got that looking good, I thought we could limit fluid simulations to boat wakes, generate those on a flat surface and then merge them into the water.”

Early renders revealing disappointing wave detail forced Knoll to face the prospect of generating fluid simulations on a scale much larger than had ever been attempted at ILM. “I wanted to avoid giant fluid simulations because they are extremely difficult to do,” explained Knoll. “I had witnessed what the *Poseidon* team had gone through to get their shots working, but unfortunately we couldn’t apply those tools directly to this film because our requirements were so different.” Previous ILM fluid simulations had been based on rectangular grids — containing an ocean surface in a large but shallow virtual box. Simulation of a deep fluid vortex required a more expansive volume and was much more computationally intensive. “We not only had to make a big round whirlpool shape, where the distribution of waves and wave motion all relied on where the ships were located, we had to contain a huge number of voxels, which required a very large memory footprint. Even our 32-gigabyte machines weren’t powerful enough to run fluid sims with the level of detail we needed to represent a whirlpool a mile across.”

Knoll worked with fluid dynamics engineer Frank Losasso Petterson and CG supervisor Joakim Arnesson to focus on the climactic storm, while also attending a 100-day production shoot with visual effects producer Jill Brooks. With Knoll away on principal photography and with only a 12-week postproduction schedule — six weeks shorter than the previous *Pirates* film — visual effects supervisor Roger Guyett joined the team to supervise the preproduction phase, the miniature shoot and ILM scenes outside the storm. “Visual effects producer Jeff Olson organized the miniature shoot,” remarked Guyett. “It was well over 200 shots, which was a massive undertaking. We started shooting while John was away, and continued right up until two weeks before the delivery of the movie.”

The production made use of miniature effects, as in previous *Pirates of the Caribbean* films, to add mast extensions to full-scale floating set pieces and to depict Jack Sparrow's pirate ship, the Black Pearl — a highly detailed, 22-foot-long, 1/6-scale model. The third film also required miniatures of several new vessels, including the East India Trading Company square-rigger Endeavour, Sao Feng's warship, the Empress, and a Chinese-junk-style pirate ship, the Hai Peng. Miniature supervisor Charles Bailey oversaw miniature construction, this time serving under the banner of Kerner Optical, on the site of ILM's former premises in San Rafael. "Every one of the original ILM model crew stayed on at our facility," stated Kerner Optical chief executive officer Mark Anderson. "Charlie Bailey, Steve Gawley, Lorne Peterson are all still here. We separated the physical production aspects from ILM's digital facility; but it's business as usual, with the same group in the same location we were in before."

Modelmakers built miniature ships making use of computer numeric control and marine construction techniques. "We built our boats in an AutoCAD program," Anderson explained. "We cut out bulkheads and the majority of the skeleton of the boats on a laser-cutter, and then assembled those like a giant puzzle. We used marine-grade plywood for internal structures and fitted bulkheads to a center keel-board with interlocking ribs, leaving space inside to allow us to get inside the hulls. The wood we used was very thin and flexible, so we didn't have to steam our timbers to bend them, like full-scale ship builders. We used pine or Douglas fir for planking, hand-laid on the outside in pretty much the same way a real ship would be built."

Kerner artists painted ships to simulate weathering and barnacle growths on hulls, sculpted and cast miniature accouterments for ornate woodwork, lamps and cannons, and developed miniature-scaled rope, hand-tied in authentic square-rigging fashion. "All our boats had working sails and rigging," Anderson noted. "We used China silks for sails, dyed to match the first-unit ships. We had to be able to match sail configurations if ships were under sail or sitting in a harbor; so it all had to be functional, with sails clewed or unfurled. Our model crew had to become quite nautically-minded and, after three movies, they got it down pretty well!"



Concluding an epic trilogy, producer Jerry Bruckheimer and director Gore Verbinski pulled out all the stops in *Pirates of the Caribbean: At World's End*. Walt Disney Pictures visual effects supervisor Charles Gibson returned with Industrial Light & Magic visual effects supervisor John Knoll to lead an armada of effects artisans that brought to life more pirate ships, sea monsters and tumultuous sea battles than the previous two *Pirates* films combined. Special effects supervisor John Frazier led the physical effects effort focused on a giant maelstrom, and Kerner Optical provided extensive miniature effects.

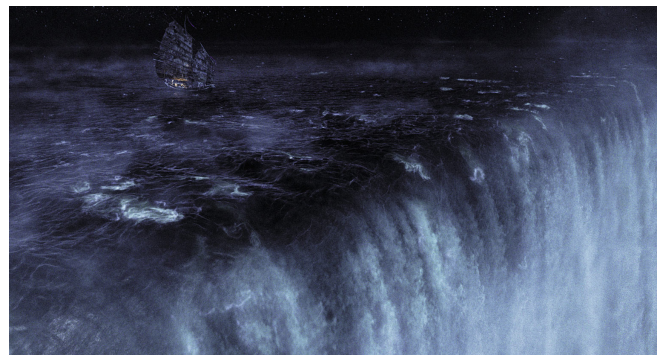
The high volume of miniature shots necessitated three directors of photography — Carl Miller, Marty Rosenberg and Pat Sweeney — shooting in four- and eight-perf 35mm film formats, depending upon required detail resolutions. Weather permitting, the crew staged most daylit model scenes on the Kerner backlot slab and more complex mechanical effects inside. Senior special effects technician Geoff Heron was responsible for all ship rigging, pyrotechnics and the construction of two water tanks — one interior, one exterior — which included wave-makers and wind fans that agitated a four-foot depth of water. To enhance the ships' stature, cameras frequently filmed close to the waterline — protected by splash-boxes and rain deflectors — and ran at high speeds to magnify scale. "We tended to shoot 1/6-scale miniatures at about 72 frames per second," remarked Anderson. "That made the sails appear to be heavy and billow slowly as the air was grabbing them. In the past we've tried techniques like adding glycerine to the water in the tank to help water scale, but a raindrop still ends up being the size of a raindrop. That's why we always tried to build our boats to scales that were appropriate to the shot."

The majority of full-scale ship work transpired during a three-month shoot in a 422,000-square-foot former aerospace construction hangar in Palmdale, California. "We filmed in the same hangar where Steven Spielberg shot *The Terminal*," explained Charlie Gibson. "We had two full-scale ships mounted on motion controlled gimbals and the biggest bluescreen I have ever seen in my life. There were deck sections of the *Black Pearl* and Davy Jones' ship, the *Flying Dutchman*. There was another version of the *Black Pearl* that capsized; a piece of Beckett's ship, the *Endeavour*, for the battle at the end of the film; and the *Hai Peng*, which our heroes borrow from Sao Feng, in Singapore. We had all of those vessels existing on stage simultaneously in Palmdale, and we managed to fill that huge space completely. The lighting requirements were incredible, with a matrix of 1,200 Spacelights mounted across the ceiling to achieve exterior daylight levels."

To create realistic interactive full-scale ship motion inside the Palmdale hangar, physical effects supplied some of the largest gimbal rigs ever constructed for motion picture use. "The Dutchman and the Pearl were on gimbals that each weighed a million pounds," stated special effects supervisor John Frazier. "All Gore needed was the deck, so we made a truss to that shape and length and built the ships from the ground up, out of timber, onto the truss. We moved the ships in and out of the shooting area



Pirate captain Barbossa and company sail on board a Chinese junk, the *Hai Peng*, to a mysterious arctic gateway to the pirate underworld of Davy Jones' Locker. Verbinski staged scenes of characters on deck atop a 90-foot-long set on a mechanical gimbal rig. For wide shots of the *Hai Peng* navigating frozen terrain, the production filmed aerial plates of a wake-producing ship in Greenland. Digital Domain then filmed and composited a Kerner Optical miniature ship into the ocean. Shots of the *Hai Peng* entering an ice cave featured the miniature among digitally generated icebergs, water and ice floes.



The *Hai Peng* is drawn toward an infinite waterfall representing ancient mariners' legendary perception of the

using ten five-foot-diameter air bearings. Then we did something that has not been done before, which worked out just terrific for us. Most gimbal rigs for ships, whether they're on two axes or six axes of movement, are mounted from the middle. For this film, we put towers at each end so we could heave the ship straight up 12 feet at one end and 15 feet on the other, like a big cradle. We then had 15-inch hydraulic rams set into the interior of the towers.

When the rams slid up and down, they gave us pitch and yaw. We could lift the bow up, and follow it back down with the fantail on the stern, and re-create all the natural movements of a ship at sea."

Mechanical engineer Ross Young and hydraulics specialist Joe Judd controlled ship motion, pumping hydraulic oil at 1,000 gallons a minute through the gimbal system. Operators used an OEM Delta computerized control system to program ship motion and provide repeated takes. Water cannons and 100-mile-per-hour fans created interactive spray, splash and gale-force winds in maelstrom scenes, pummeling cast and crew to grueling effect. "I've never been on a gimbal where you could actually get seasick," said Frazier. "The motion on that ship was just phenomenal. I think it was one of the most impressive gimbal rigs anybody has ever done."

Storm conditions put the ILM iMocap team through its paces, using high-definition Sony Handycams to help capture creature performers amid the elements. "Our witness cameras were pretty lightweight and easy to position," stated Hal Hickel. "From time to time, grips helped us if we needed a special camera mount, but generally we just stuck the cameras on little tripods wherever we had clear views of the characters. When they really started to hit us with rain, our matchmove lead, Jason Snell, who was always manning one of the cameras, ran to the local Home Depot, bought a plastic garbage can, cut it up and made a rain housing for the camera. It was goofy-looking, but it worked great." In addition to the Palmdale shoot, the production shot ocean scenes off the coast of Southern California and interiors on soundstages at Universal and Disney Studios.

The intense production schedule required a battery of additional visual effects vendors in the Los Angeles area. "This show has as many visual effects shots as the first two movies combined," said Gibson. "We had more than 2,000 visual effects shots. ILM had a capacity for about 750, so we ended up with another seven vendors." All visual effects material flowed through the cutting room of visual effects editor Chris Capp, who tracked Avid files using a FileMaker Pro database adjacent to rooms occupied by film editors Stephen Rivkin and Craig Wood in the former Ink and Paint building on the Disney lot.

edge of the earth. To provide real-world visual reference, Charlie Gibson and members of the production's aerial unit shot footage of Niagara Falls, emulating camera angles designed in previz. Digital Domain sampled the footage mostly as reference material and generated both the waterfall and the Hai Peng digitally. Artists used fluid simulations to create turbulent flows near the edge of the falls, creating a continuous surface with swirling whitewater and eddies many times the height and breadth of Niagara.



Jack Sparrow fights a losing battle with his wits as he struggles to survive the torments of Davy Jones' Locker, a parallel dimension resembling an arid landscape, where the pirate captain has been incarcerated since his demise in the previous sequel. Verbinski filmed establishing shots for the sequence at the Bonneville Salt Flats, in Utah, where production designer Rick Heinrichs erected a scaffold representing part of Sparrow's pirate ship, the Black Pearl. ILM composited a Kerner Optical miniature

Veteran of all three Pirates films — and supplier of the trilogy's parrot voice — Capp provided Verbinski with constant access to the evolving postproduction process. "Gore came into the cutting room

constantly with concept ideas and changes," explained Capp. "I then dealt directly with the visual effects producers at our various vendors — Jill Brooks at ILM, Kim Covate at Asylum Effects, Kelly L'Estrange at Digital Domain — and Charlie and I dealt with all the bids. It was tough because, out of approximately 3,000 cuts in the whole film, half of the last film and two-thirds of this film were visual effects. Pirates 3 was also harder than Pirates 2 because Gore was shooting almost all the time, so we had no time for vendor turnover meetings. We tried to be very conscientious of budget — we took shots to a certain level of completion, and then Gore would show us the way to go."

For the film's opening scenes in Singapore, production designer Rick Heinrichs built an expansive set on Stage 12, the largest soundstage on the Universal lot, depicting an Asian waterfront setting flooded with three feet of water. For wide establishing views, ILM digimatte supervisor Chris Stoski created a digital matte painting of the city and its environs, based on conceptual art. "Anybody who has been to Singapore will notice a little difference in our city," noted Roger Guyett. "The geographical location is actually pretty flat, but we have mountains in ours. They must have worn away over the last 100 years!"

For soundstage scenes peering up into the perms, Digital Domain and CIS Hollywood generated additional digital matte paintings to extend the environment. CIS enhanced an action sequence that occurs with the arrival of the East India Trading Company, adding smoke trails and musket blasts to practical pyrotechnics. "It's not realistic to see musket trails from flintlock rifles," said CIS visual effects supervisor Bryan Hirota. "But Gore wanted to help illustrate how our heroes were being shot at, providing enough information to make a point without the effects becoming distracting. We used combinations of digital particles, *Inferno* work and a bunch of muzzle flash elements that Charlie Gibson shot to help give the effects an organic feel."

Barbossa and Swann enter a bathhouse to rescue Will Turner from Sao Feng and encounter exotic characters created by makeup designer Ve Neill and lead makeup artist Joel Harlow's prosthetic effects team. "We had a different look for the Chinese pirates," Harlow observed. "Gore wanted to set them apart from pirates that we'd seen in the previous two movies by making them more diseased or deformed." Harlow applied a cleft lip and boils onto the face of Tai Huang (Reggie Lee), Sao Feng's right-hand man. Neill and Harlow applied detailed scar makeup to Sao Feng and created a variety of looks for the warrior's long beard and mustache — worn loose in the bathhouse meeting, later braided and tied back for battle.

into the plates and animated a horde of ellipsoidal rocks that magically sprout crab-like appendages and scurry to Sparrow's aid.



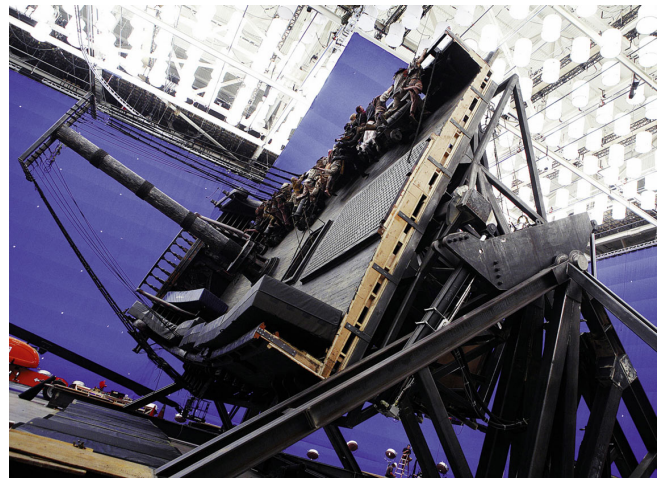
Sparrow uses demented logic and voodoo magic to escape Davy Jones' Locker by capsizing the Black Pearl in an ocean at sunset, affecting its reappearance at sunrise in the mortal realm. The production initiated the sequence with performers on an oceangoing set representing the Black Pearl, filmed off the coast of Southern California. Shots of the vessel rolling into the ocean, dunking all on board and then righting itself again featured large-scale mechanical effects, closeups of performers on an underwater bluescreen set, Kerner Optical miniatures

Verbinski suggested a bizarre detail for bathhouse denizens who had succumbed to local vices. “Some guys had been sitting in this rancid bathwater for so long,” Harlow observed, “they had mushrooms growing out of their skin. We created those as modular makeups using foam latex appliances with sockets in them and smaller mushrooms sculpted to fit into the appliances. We then made additional flexible urethane mushrooms to stick on people’s bodies for larger fungal growths.”

filmed both dry and wet-for-wet, and wide shots of a CG ship generated at ILM.

Barbossa and company escape Singapore on Sao Feng’s Chinese junk, the Hai Peng, evading Davy Jones and his cursed crew on the *Flying Dutchman*. The production filmed scenes with Bill Nighy portraying Jones wearing his iMocap leotard with tracking bands and tracking dots on his face, but this time without any facial makeup. “The raccoon-like paint around Bill Nighy’s eyes had always been our Plan B,” explained Hal Hickel. “We asked them not to add that this time, because we had put Gore’s fears to rest with our CG character. *In fact, the makeup made it harder for us to study Bill’s performance when we were animating Davy’s face. The more clearly we could see how his skin was moving, particularly around his eyes, mouth and brows, the better off we were.*”

Another innovation for *Flying Dutchman* scenes included practical creature costumes, which costume designer Penny Rose’s team built for distant background and out-of-focus foreground shots. “As we were cutting the film,” said Charlie Gibson, “we realized that some shots only had a tiny piece of a Dutchman character in a motion capture suit, so we went back to the bluescreen stage and shot these shaggy barnacle suits against bluescreen for wherever we saw just a sliver of a character in shot. It was quite helpful, budget-wise, and helped with ILM’s workload.” Asylum composited the suit performers, matching atmospheric effects and colors of ILM iMocap characters.



John Frazier’s team built a gimbal rig for shots of Sparrow’s crew racing back and forth across the deck, causing the Black Pearl to roll. The rig – erected on a huge bluescreen stage in a former aircraft construction hangar – consisted of a portion of the ship’s deck mounted 30 feet above the studio floor on a giant hydraulic spindle.

The Hai Peng sails in search of Jack Sparrow, traveling through a mysterious arctic location known as the 'Farthest Gate.' For closeups of characters on deck, John Frazier's team mounted the 90-foot Hai Peng on a gimbal rig in Palmdale. Snow effects coordinator John Gray and team, from effects specialists Snow Business, then iced up the set using sprayable paraffin wax, acrylic icicles hung from rigging and Epsom salts as snow. Digital Domain generated running backgrounds for dialogue scenes and, for wider shots, integrated a Kerner Optical 1/12-scale miniature into location plates shot in Greenland. "Our miniature schedule was so tight," commented Gibson, "Kerner Optical built the Hai Peng and shipped it down to Digital Domain. Visual effects supervisor Erik Nash then shot the ship at Digital Domain and oversaw all the effects for the sequence."



ILM matchmoved shots of the full-scale rig and developed previsualizations that drove a corresponding camera move on a Kerner Optical rig built by senior special effects technician Geoff Heron to capsize a miniature Black Pearl in a water tank.

The Greenland shoot involved helicopter plates of a camera boat filmed passing through icebergs, creating practical wake effects. "We used our proprietary tracking software to figure out where the boat was in space," related Erik Nash. "We then derived a camera relationship to that and used that data to shoot the miniature, covering up the real boat in the aerial plate. I shot the miniature myself here at Digital Domain. It's so rare these days that we get to shoot miniatures, I didn't want to let somebody else have the fun!"

Under the supervision of Digital Domain model supervisor Alan Faucher, Snow Business iced up the eight-foot Hai Peng using techniques similar to the full-scale set. The mechanical effects team then positioned the miniature ship on a motion control track in the Digital Domain parking lot, with the camera above in the basket of a Condor lift. "We wanted to avoid putting a big motion control rig way up in the air," observed Nash, "so we decided to move the boat instead of the camera. We had the camera on a motion control pan/tilt head, between 30 and 80 feet in the air, and rigged the boat with actuators built into the hull controlling yaw, pitch and roll as it traveled down its track." The shoot required an interactive 20-by-20-foot lighting rig to create dynamic effects of arctic sunlight. "Light in the Greenland plates was very soft, but it was also very directional because the sun was low and the camera passed through a lot of atmosphere; so we had to move the keylight on a parallel motion control track to keep it in correct orientation to the plate."

Digital Domain compositing supervisor Sonja Burchard and her team blended the miniature into plates for the first two shots of the sequence. Closeups of characters on deck included composites of interactive icy breath. “We shot real icy breath elements in an enclosed cold room against black,” Nash explained. “That’s always tricky to do, because you have to control not just the temperature, but also the humidity, keeping moisture in the air. We shot it like a dialogue replacement session, using playback for each character separately. That included Barbossa’s pet monkey — he didn’t have any lines, but we had to be prepared, so we shot some elements for him.”

The balance of the scene, including shots of the Hai Peng sailing into an ice cave, relied on an expansive 3D matte painting of towering icebergs with CG water, floating ice chunks and slush. Digital Domain matte paint supervisor Wei Zheng oversaw creation of 3D ice formations mapped with textures based on Greenland plates. “We were initially worried about replicating translucency in the ice,” remarked Nash. “But once we saw the plate photography, we realized the ice was snow-covered and frontlit, as opposed to backlit and translucent. We took cues from the plates — the quality of the ice, scale of detail and size relationships of the huge ice cliffs relative to the boat — and we extrapolated from there, changing the geography into tall, looming spires that converged above the ship.”

The Hai Peng is next seen at night on a mirror-like ocean surface, precursor to a much more violent scene in which the ship is drawn over a giant waterfall representing the ‘Edge of the World.’ Digital Domain generated both environments digitally. “The dynamics of how the boat had to move were so extreme,” observed Nash, “there really wasn’t a viable miniature solution. We had sweeping helicopter camera moves; the ship had to interact with the water; there were CG characters on deck and in the rigging; the sails had to move with extreme cloth dynamics — all of those factors



Kerner Optical gaffer Frank Strazalkowski attends to the intricate miniature of the Black Pearl. Kerner Optical reconvened many principal staff members from ILM’s former model shop, including miniature supervisor Charles Bailey who oversaw fine detailing of the miniature that the team originally built for *Pirates of the Caribbean: Curse of the Black Pearl* and then refitted for the first sequel, subtitled *Dead Man’s Chest*. Modelmakers used computer numeric control to cut bulkheads from marine-grade timbers, hand-laid planking over the skeletal structure, stained and weathered hulls, and then

required a CG ship. The snow and ice treatment on the Hai Peng was also distinctly different from the earlier part of the scene. So it was a logical break-point to use a CG ship on the flat, calm ocean.”

fitted the vessel with functional miniature sails and rigging.

To capture organic detail of the ship, Gentle Giant Studios provided a lidar scan of the 90-foot-long Hai Peng set in Palmdale. “It was a colossal endeavor,” remarked Gentle Giant vice president of operations Brian Sunderlin. “We had done scanning on the previous Pirates films, but this was a first for us. The production wanted a highly-detailed scan of the exterior of the ship, including all the deck, props and ice effects. *Initially*, we laid down markers, took establishing scans, which we then used to patch together subsequent detail scans. The point-cloud we captured was so dense, we had to write custom ‘voxelization’ software that allowed us to retain all the ropes, props, masts and sails. The voxel format was ideal for Digital Domain’s next step in processing the model in Cyberware Cyslice. It was one of the largest and most complicated models we’ve built.”

Digital Domain CG supervisor Darren Hendler oversaw construction of the CG ship, using Gentle Giant geometry. The ship was textured with photographic imagery of the miniature and full-size ship, detailed with CG set dressing derived from photographs of full-scale props shot in a black-screen photo booth in Palmdale. Compositors integrated the digital ship into a mirrored ocean surface, stars above and below, and then introduced layers of mist as the Hai Peng moved toward the waterfall environment.

The waterfall represented an ancient mariner’s legend of a plunge over the edge of the earth into an infinitely deep abyss. “It was a perspective impossibility,” remarked Nash. “Even if the earth was flat, like a dish, what would be the radius of that dish? We were starting to wrestle with that concept, when Gore let us off the hook. He realized it didn’t make any visual sense, so he decided not to reveal the whole waterfall on camera.”

The waterfall is first seen in a sweeping aerial shot that tracks back from the Hai Peng to reveal a portion of the crest of the waterfall plunging down, out of frame, into a cloud of mist. *In preparation for the sequence*, Charlie Gibson, aerial coordinator David Paris and aerial director of photography David Nowell shot aerial plates and textures of Niagara Falls. “We had access to the falls beyond normal



Modelmakers Wendy Morton and Lorne Peterson dress a miniature of the East India Trading Company triple-decker flagship Endeavour on the Kerner Optical stage. The Endeavour, a redress of the Dauntless from Curse of the Black Pearl, was one of several new miniature ships built for the climactic sequel. Kerner rigged most daylight model scenes on its backlot slab and staged more complex mechanical scenes inside. The model team filmed ships in water tanks with wave-makers and wind fans agitating a

tourist views,” explained Gibson. “We shot angles with the helicopter pulling back to reveal the falls, angles from underneath, frontal views and perspective views, trying to re-create shots in the previz.”

four-foot depth of water, with cameras over-cranked to simulate the effects of wind filling much larger sails.

Digital Domain sampled the Niagara Falls footage mostly as reference material. “Charlie shot thousands of feet of really gorgeous material,” commented Nash. “That footage became a library of information for the water’s scale and its behavior as it went over the edge. It was such a wild concept, we wanted to ground the fluid dynamics in reality, in terms of acceleration and drag from the air as the water particles atomized. We used some of the Niagara footage in shots for a teaser trailer, and we used little bits and pieces as sweeteners in our composites; but for the most part our waterfall was completely computer generated.”

Digital Domain visual effects concept artist Claas Henke generated conceptual art that guided creation of the synthetic falls. CG effects animation lead Jens Zalzala’s team then ran hundreds of fluid simulations to create turbulent lows near the edge of the falls, combining fluid simulations with the CG Hai Peng and waterfall environment to create a continuous ocean surface complete with swirling whitewater and eddies. To create an impression of scale many times the height and breadth of Niagara, animators created multiple volumetric data sets simulating small water features atomizing as they fell through the air. Artists then replicated data sets millions of times using Digital Domain’s voxel-based renderer, Storm, creating full volumetric renders of the vast waterfall, and compositors integrated elements with multiple layers of swirling mist.



After returning to the mortal realm, the Black Pearl runs afoul of Chinese warlord Sao Feng on board his warship, the Empress, and then engages the Endeavour in cannon fire. The production staged the action sequence in the open ocean using a full-scale Black Pearl set – with deck and hull, but only the lower portions of its masts – built around a smaller sailing vessel. ILM added Kerner Optical miniature sail extensions to the Black Pearl live-action and composited miniatures of the Endeavour and the Empress into the ocean, with pyrotechnic elements and atmospheric haze.

John Frazier’s crew simulated closeups of the plunge on the Hai Peng deck, tipping stunt players and principal performers on a full-sized gimbal set that dipped from level to a 30-degree pitch. Digital Domain animated wide shots, including an angle positioned below the lip of the falls where the Hai Peng plunges past camera — with careening animated crewmen, rippling dynamic sails and rigging — and then disappears into the mist.

Jack Sparrow, meanwhile, is discovered miraculously alive in Davy Jones’ Locker. “Davy Jones’ Locker is where the kraken took Jack at the end of the last movie,” explained Charlie Gibson. “It was a parallel dimension, a place where no pirate sailor would ever want to go — in the middle of a desert. The Black Pearl was there, also intact. It was a very strange and weird place.” The production filmed establishing shots for the sequence on the sun-baked Bonneville Salt Flats, in Utah, and applied a high-contrast, bleach bypass look in postproduction, rendered by digital colorist Stefan Sonnenfeld at Company 3.

To represent the Black Pearl on location, Rick Heinrichs erected a scaffold representing part of the pirate ship hull. ILM then integrated a 1/6-scale miniature ship, beached on its side, filmed in natural sunlight at Kerner Optical. “We had used a similar technique to put the Black Pearl on the beach on *Cannibal Island* in *Pirates 2*,” observed John Knoll. “We built a decking as close as we could to the color and texture of the salt flats, shot the elements to match, and then split them in.”

Sparrow crews the Pearl in a state of dementia even more pronounced than previous films, seeing visions of multiple Jack Sparrows populating the ship. Ve Neill and Penny Rose devised looks for multiple Jacks that Johnny Depp and eight body doubles performed on set. “The doubles all had black eye makeup, goatees, dreadlocks and roughly the same physical build,” explained Joel Harlow. “Some of them were shirtless, some had different tattoos. Makeup artist Ken Diaz created some pretty extreme tattoos, particularly for Cabin Boy Jack who had a full upper torso tattoo.”

For scenes featuring Sparrow interacting with his doubles — and, at one point, stabbing a subordinate Jack — visual effects blended repeat takes of Depp. “We used every trick in the book,” remarked Gibson. “We shot some elements on the ocean in Southern California. Others, where we needed better control over lighting for multiple passes, we shot on a bluescreen stage with *Image G* handling motion control.” To guide Depp’s performances, the production made a premix of Sparrow’s dialogue, played back the track on set and muted whatever character Depp was playing. Asylum visual effects supervisor Phil Brennan and compositing supervisor John Fragomeni then rotoscoped and blended elements, layering up to 20 Jack Sparrows into the scene.

Sparrow escapes the desert with the assistance of small ellipsoidal rocks that magically sprout legs. “It was a really odd idea,” said John Knoll. “Tia Dalma remotely summons all these rocks, which are like big M&Ms, five inches across. They unfold in an amusing way into something that resembles a stone crab, and a few hundred thousand of them cooperate to pick up the Black Pearl and carry it across the desert.” ILM animated the crabs using cycles of keyframe animation randomized throughout the cast of crabs, with hero crabs animated by hand.

To shoot the Black Pearl in motion, sailing over a dune sea on top of the crabs, the production filmed background plates in the *Rancho Guadalupe Dunes* Preserve, in Santa Maria, California. Kerner Optical then collaborated with ILM to film elements of the 22-foot miniature Black Pearl moving in perspective to the background plates. “The combination of CG layout and miniatures was such a powerful tool,” commented Roger Guyett. “Jason Snell’s layout department figured out perspective changes on the ship; and then we shot the miniature on the slab at Kerner. The Pearl was fixed in space and we moved the camera to make the ship appear to be moving, blowing fans to fill the sails. We then tracked the photographed Pearl back into shots.” Compositing supervisor Eddie Pasquarello’s team combined elements with dust particles simulating the wake of tiny stone crabs surfing the dunes, and layered a greenscreen element of Jack Sparrow onto the Black Pearl miniature. For distant angles of the ship arriving at a beach bordering the dunes, where survivors of the wreck of the *Hai Peng* have gathered, Kerner Optical fitted the miniature Black Pearl with an 11-inch-tall puppet Jack at the bow.

Reunited with his old accomplices, Sparrow sails aboard the Pearl into the doldrums of an ocean where, at nighttime, crewmembers witness bodies of other lost souls drifting by the ship. The

production filmed the scene partially on the deck of the Black Pearl at sea and partially on an interior water tank at Palmdale with a black backing and practical drifting fog.

The Orphanage extended sets and added a shoal of ghostly bodies submerged in the ocean. “Charlie Gibson picked eight or nine interesting-looking people to play the ghosts,” noted Orphanage visual effects supervisor Kevin Baillie. “We set up a series of strobe lights around the actors to create flat lighting, shot them for texture reference and then re-created all the bodies digitally. We started with a base model, then used texture reference to shape them in ZBrush and Mudbox, painting detailed displacement maps to create likenesses of the performers.” To clothe characters in nightgowns that appeared to waft in the underwater current, Orphanage creature supervisor Corey Rosen used Syflex cloth simulation software based on practical reference. “We submerged someone wearing a ghost gown in a swimming pool, placed Sea-Doo Seascooters in the water and ran a current over the costume underneath the surface of the pool. We took a lot of video reference of how the fabric flowed, and then mimicked that with our cloth simulations.”

Rosen’s team modeled nine ghost bodies with interchangeable gowns and hairstyles. Orphanage 2D supervisor Mike Terpstra oversaw the compositing in Eyeon’s Digital Fusion and replicated up to 50 bodies in wide shots, while CG supervisor Brian Kulig oversaw shading and rendering, illuminating characters with an underwater light source and underwater atmospheric effects. “We threw the kitchen sink into our composites to make the bodies read,” related Baillie. “Each body cast its own shadow through the underwater volume. They had subsurface scattering for their skin and gowns, translucency in the fabric, normal maps and volumes in the hair, all layered underneath a refractive 3D water surface.”

Following the floating bodies, a fleet of small dinghies drifts into view, containing more lost souls holding lanterns that illuminate their faces. Ve Neill’s makeup team created ghostly makeups for ghost performers. The production filmed rowboats from a crane overlooking the Palmdale water tank. *The Orphanage* extended the flotilla by interspersing 2D elements with more distant 3D rowboats, using a digital ocean surface to blend hulls into the water surface. Compositors then added practical mist elements, lantern halation, flicker and reflections.

The ghostly visions unnerve the Black Pearl crew, causing Ragetti (Mackenzie Crook) to lose his prosthetic wooden eye — a recurring gag handled by CIS Hollywood and *The Orphanage*. Crook wore a scleral contact lens in his right eye — wood-patterned for scenes with the eye inserted, black for scenes with the eye socket vacant. “We matchmoved Mackenzie’s head,” explained Bryan Hirota. “For hollow-socket shots, we added geometry representing the eyelids and the inner eye-socket, and lit and rendered that into his head. Other times, we animated a CG eyeball, matching the movement to his real eye and then offsetting that to make it out of sync. We toned it down quite a bit this time, because Gore didn’t want the audience to become tired of the gag.”

Elsewhere on deck, Jack Sparrow’s multiple personalities manifest again, this time in the form of miniature Jacks that appear on his shoulders to argue strategies for escaping Davy Jones’ Locker. Verbinski filmed Depp in conversation with Sparrow’s imaginary miniature alter egos on the ocean-going Black Pearl set, using dialogue playback and Q-Tips on Depp’s shoulders to guide the performance.

To shoot miniature Jack elements, Rick Heinrichs built a 19-times-oversize Jack Sparrow shoulder rig in Palmdale, upon which Depp could clamber and interact with giant beaded dreadlocks, filmed against bluescreen. Method Studios — a long-time collaborator in Gore Verbinski's commercials work — then integrated tiny Jacks with large- and real-scale hair textures and production plates. "Johnny was suspended on a wire on the bluescreen rig," related Method visual effects producer Aaron Kisner. "He had guys beneath him swinging him about, but there was no motion base or sophisticated equipment creating motion in the hair or shoulders. That was up to us."

To help track elements to the plates, Method CG creative director Laurent Ledru built CG models of full-size and miniature Jacks, complete with jewelry festooning Sparrow's hair. "The 3D models allowed us to lock Little Jack to Johnny's shoulder and make sure his size was consistent as Johnny moved his head," noted Method visual effects supervisor Alex Frisch. "We digitally re-created the medallion in his hair, and the chain, and the yellow and orange beads that Little Jack clung onto. They had oversized beads on set, but our CG versions gave us a much better match to the beads in Johnny's hair. When Little Jack swung about, we animated chains to swing below him, using natural physics, and animated the beads and impacts with the medallion on its chain." Method compositors reconstructed plates with footage of a stand-in wearing a Jack Sparrow wig, added digital stray flyaway hairs and blended elements in Autodesk Flame and Apple Shake.

To escape Davy Jones' Locker, Jack Sparrow incites the crew of the Black Pearl to run from side to side on deck, causing the ship to capsize and then right itself at daybreak in an ocean in the mortal realm. Verbinski initiated the sequence with footage of performers on the Black Pearl filmed off the coast of Southern California. CIS manipulated the shots digitally, replacing the sky with a golden sunset effect, and rebuilding the ocean and horizon line to create the illusion of a rocking ship.

For shots of characters rocking the Black Pearl to more extreme angles, Verbinski shot actors on a custom hydraulic rig in Palmdale. "We made a gimbal that could roll 110-degrees in two directions," related John Frazier. "We built a special platform, about 30 feet high, connected by two rams that allowed the rig to roll. It was quite a complex rig that allowed us to not only do teeter-totter moves from side to side, but almost completely rotate it."

The ILM layout department matchmoved shots of characters on the full-scale gimbal rig and developed previsualizations to drive a corresponding miniature camera move on a 1/6-scale Kerner Optical rig capable of spinning the miniature Black Pearl through the 25-by-35-foot water tank. "We wanted to get water interaction as a practical effect," said Roger Guyett. "The difficulty was, shooting at 72 frames per second to try to help the scale, we had to spin the ship at three times normal speed. We were rotating this huge 22-foot-long miniature through 90 degrees in about a second. Geoff Heron and his team had to engineer the bejeezus out of the rig to counteract the resistance of the water. We blew up a few motors and, at one point, we accidentally split the Pearl in two."

Carl Miller illuminated the miniature with banks of 20K lamps, pounding the ship with light to provide maximum depth of field, and staged motion control moves based on ILM tracking data. Modelmakers dressed the ship for each take with miniature equipment fastened to the deck, the sails clewed, and then wave-maker rigs agitated the water. ILM sequence supervisor David Weitzberg and Sabre lead Grady Cofer assembled wider CG angles of the Black Pearl rocking on its keel, seen from a perspective looking up through the surface of the water.



The threat of Davy Jones' alliance with the East India Trading Company causes pirates to convene on Shipwreck Island, a remote haven containing the wrecks of ruined sailing vessels piled into a conglomeration of rotting hulls in a cove at the center of the island. ILM generated wide shots of the island and the stack of ships inside Shipwreck Cove as digimatte synthetic environments, using photographic textures and mixtures of 2D and 3D digital projections. Verbinski filmed interiors on an elaborate set at Walt Disney Studios.

For closeups of characters plunged underwater, Verbinski filmed principal performers submerged in a partial bluescreen set in a water tank at Universal. Wide views of the inverted ship featured both the CG ship and miniature version filmed 'dry for wet,' using smoke to create the impression of underwater haze. "Geoff Heron's guys lifted the 1/6-scale Black Pearl up into the ceiling of the stage," said Guyett. "We rotated it on what some smart-aleck called a 'boatisserie.' We had the miniature on a spit and controlled its spinning motion as it swung upside-down. We made the sails appear to drag against the resistance of the water by shooting back to front, so gravity made the sails hang the other way." For wide shots unachievable with the inverted miniature, ILM generated a CG ship using textures from the practical model applied to the CG vessel, and applied interactive cloth simulations, clouds of bubbles and debris.

The Black Pearl breaks through the ocean surface, returning to the mortal realm — generated at ILM with the CG ship penetrating a digital water surface. The ship resurfaces at the moment of an atmospheric phenomenon known as a 'green flash' — a rare natural event, at sunrise or sunset, in which light refracts through atmospheric inversions to create a green ray of light above the sun. Grady Cofer generated the effect in Sabre using lens-flare processing. "Gore wanted the green flash to have a personality," related Guyett. "It was a big story element that took characters from one world to another, and it had to have a characteristic that gave it that level of importance. We made it a little bigger than the atmospheric effect that occurs in nature, making it slightly supernatural, but tried to keep it in the realm of the believable." Pacific Title generated sky replacements for subsequent shots of the Black Pearl's return to the mortal world, creating a vibrant color palette to contrast the high-contrast look of Davy Jones' Locker.

Jack and Barbossa put ashore on a beach where they discover a lifeless squid-like sea monster — the kraken from Dead Man's Chest. Verbinski filmed performers interacting with a large rubbery bluescreen form representing the kraken corpse on the Caribbean location. ILM compositor Tory Mercer replaced the prop with the CG creature model generated for Dead Man's Chest, which James Tooley's team rigged to make tentacles appear to float in the surf, and rendered with a blubbery flesh simulation.

The Black Pearl runs afoul of other adversaries, first Sao Feng and then Davy Jones, leaving Elizabeth imprisoned on the *Flying Dutchman*, where she meets Bootstrap Bill (Stellan Skarsgård) fused into a bulkhead. Skarsgård performed the scene in an even greater state of decay than his last appearance, continuing a progression of six makeup stages designed for the sequels. “Bootstrap’s makeups were all based on Crash McCreery concept art,” said Joel Harlow. “Stage Four, in the Dutchman brig, had a lot more happening on the left side of the face, with barnacles and growths on the face and neck. Everything that we had on him previously, we amplified, leaving his eyes clear, which Gore still wanted to read.” ILM added CG coral that crumbled away as the character moved, achieved using a rigid simulation devised by James Tooley’s team, and additional shellfish, including mussels and a giant animating clam.

Bootstrap appears at his most ravaged stage later in the film. “We gave Stellan a vacuform helmet with pieces of coral and mussel shells growing out of it,” stated Harlow. “His pirate hat had completely rotted away, so we blended growths out of the top of his head with sea life growing out of his face. Stellan particularly requested gooseneck barnacles, so we threw in some of those long, tendrilly growths to make this special for him.” The elaborate makeup was featured in the finale of the film amid swashbuckling action devised by stunt coordinator George Michael Ruge. “Bootstrap was sword fighting while being drenched. Water is not a friend of makeup, so we zinced around his mouth and neck, where the prosthetic was heaviest, and it stuck pretty well. We also made stunt makeup for Stellan’s stunt double, Rob Mars. We attached appliances to Powernet that fitted over his head and chest. We did a paint makeup on his hands, slipped on a vacuform face piece and he was ready to go in about half an hour.”

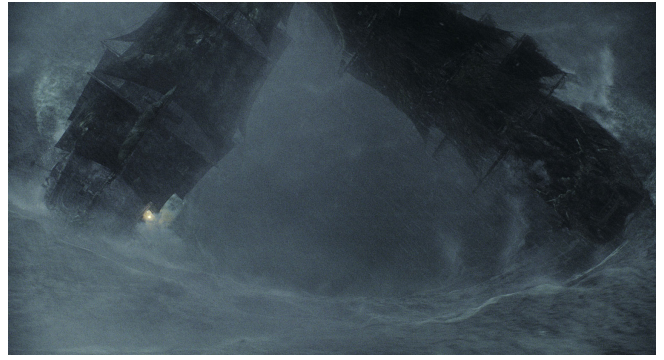
Jack Sparrow evades capture and sails the Black Pearl to a remote pirate haven on Shipwreck Island. For views of the island seen from the deck of the Pearl, Verbinski shot foreground characters on the Black Pearl set piece in the open ocean. ILM generated wide views of the island and angles of the ship entering a cove as a hybrid 3D environment that digimatte artist Brett Northcutt created in ILM’s Zeno software platform. “The establishing shot was a big helicopter move,” noted John Knoll. “It flew in a 270-degree arc around Shipwreck Cove and was almost entirely 3D. We used some photographic textures, but it was pretty much synthetic, with painted renders projected to create a nice mixture of 2D and 3D. Inside the cove, we generated a giant stack of wrecked ships converted into apartments, with ladders and walkways between them. It was a really odd and whimsical concept.”



The Black Pearl approaches a supernatural phenomenon that churns the ocean, initiating a tumultuous maelstrom that occupied 20 minutes of screen time. ILM focused its research and development for the film on maelstrom effects, drawing on its past experience with digital oceans and experimenting with techniques to create sufficient wave detail while wrangling massive renders. For early shots of the ocean beginning to swirl, ILM integrated the first stage of an enormous fluid simulation into ocean plates filmed in the Caribbean, and generated a giant rotating disc of cloud using sprite elements of fiberfill clouds animated in Zenviro.

For the cove interiors, Rick Heinrichs designed an elaborate set at Disney Studios, including a meeting hall inside the rib cage of a ship. Denuded spars gave views onto further wreckage built 20 feet behind the main set, backed with a painted cyclorama.

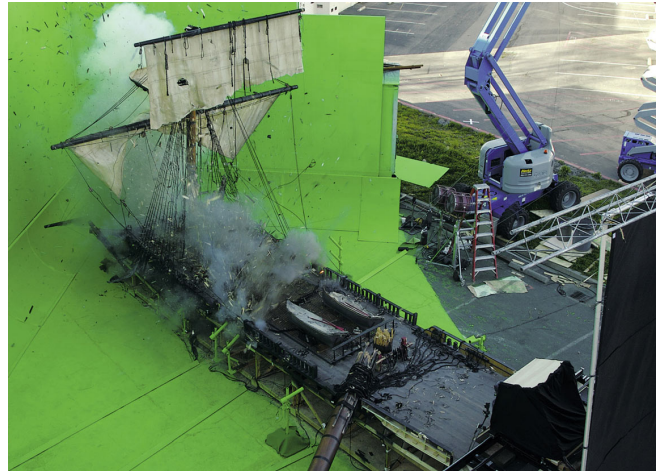
The meeting hall housed the international pirate ‘Brethren’ who have gathered there to plan a strategy against Davy Jones’ alliance with the East India Trading Company. Crash McCreery generated conceptual art for the motley buccaneers, which Ve Neill’s team realized as practical makeups. “The actors who played the Brethren pirates all had very specific physical characteristics,” related Joel Harlow. “We just augmented that. There was a Frenchman named Chevalle (Marcel Lures), who we gave a very pale-faced Louis XIV look. The Spaniard, Captain Villanueva (Sergio Calderón), had a very lined face, so we made him even more heavily scarred. The most extreme makeup in the Brethren was the leader, Captain Teague (Keith Richards). Ve Neill did that makeup herself and it was just beautiful, especially the beard work. Teague was really the crowning achievement of all the pirate makeups.”



The masts of the Black Pearl and Davy Jones’ cursed pirate ship, the Flying Dutchman, become entangled inside the mile-wide whirlpool at the center of the maelstrom. To film live-action portions of the sequence, the production staged a three-month shoot with performers on full-scale gimbal rigs engineered by John Frazier and his team. Wide angles of vessels caught in the storm featured CG ships in a synthetic environment that pushed the limits of ILM’s digital technology, incorporating particle animation, physics-based modeling, and fluid simulations derived from a partnership with Stanford University’s PhysBAM project.

While the Brethren meet, Davy Jones appears to Tia Dalma, who caresses his monstrous face, which fleetingly reverts to the pirate’s former human self. Nighy played the scene in human pirate attire with makeup designed and applied by Ve Neill, including a beard with braided dreadlocks suggesting the vestiges of tentacles. ILM then matchmoved Davy’s animated character to Nighy, revealing Nighy within. “In the moment that we went from human back to Davy’s creature features,” explained Roger Guyett, “we lined up Bill Nighy’s eyes with the creature eyes; but the physiology of their faces was quite different. We wanted it to seem like a natural transformation, not just a dissolve, so we built a lot of shapes into the CG Davy face to give us a more human version of Davy and used those to do a more complex 3D shape-change.” Sequence leads Robert Marinic and Jen Howard worked with compositor Michael Cordova, Geoff Campbell’s modeling team and Hal Hickel’s animation team to orchestrate Jones’ shifting features during the lengthy dialogue scene, shrinking facial tentacles into Nighy’s beard and blending physical forms.

The Brethren elects to fight Davy Jones and the East India Trading Company and sets out in a pirate fleet, only to be greeted by an even larger armada of East India ships that emerges from a fog bank. The production shot reference for the scene with the Black Pearl and the Empress in the Caribbean. ILM then assembled shots using mostly digital ships blended into production plates. “Grady Cofer and Chad Taylor did an amazing job of putting the fleet together in Sabre,” noted Eddie Pasquarello. “They used pieces of the full-scale Black Pearl, pieces of the practical models, and pieces of our CG ships. In wide shots of the full armada, we had 400 East India Trading Company ships facing 40 pirate ships, and all the ships were computer generated.”



As the maelstrom abates, surviving pirate ships attack the Endeavour with cannon fire that causes the warship's ammunition magazine to detonate. Kerner Optical built a series of miniatures for the Endeavour's destruction, including a 36-foot-long section of the deck, photographed in natural sunlight on the facility's backlot slab. Geoff Heron's team rigged approximately 90 pyrotechnic events to detonate in rapid succession, simulating the effects of a hail of cannon balls from port and starboard smashing through timbers, igniting a fiery detonation below deck that caused planking to erupt and toss debris toward high-speed cameras.

To create the East India Trading Company and pirate fleet, ILM digital model supervisor Bruce Holcomb supervised construction of 15 sailing vessels categorized with two levels of detail. “Ships were either fairly far in the background where they were most numerous,” stated ILM digital production supervisor David Meny, “or they were pretty close to camera where we needed as much detail as possible. Bruce’s team produced five high-resolution and ten medium-resolution ships, which still held up fairly close to camera. We then used rigging, sails and parts derived from the same toolkit, and got a lot of mileage out of replacing flag patterns and simming the sails to create very distinctive silhouettes. If we found any noticeable repeating patterns, we painted on top of our final renders to add more variation.”

Digital Domain assisted with the pirate fleet, filling out backgrounds with CG ships built from ILM’s digital models, outfitted with custom cloth simulations, lighting and texturing. “We tried to create as much variety in the pirate ships as possible,” stated Digital Domain visual effects supervisor Bryan Grill. “There were European, Asian and Middle Eastern ships of all descriptions. The Chinese junks all tended to have a certain look. The other ships varied in size, texture and color differences in their banners. We used textures from ILM, the Kerner Optical miniatures and the full-scale ships in Palmdale; and we sometimes shared shots. ILM rendered the East India armada, which we put into our pirate fleet shots, and vice versa.” Digital Domain CG supervisor Swen Gillberg and compositing supervisor Lou Pecora integrated ships into a CG water surface rendered in Storm, and populated vessels with bluescreen elements of pirates filmed during the Palmdale shoot. “We shot different types of pirate action to cover 116 shots. We had groups of 10 or 15 people — mingling, talking, cheering, operating their stations — and kept mixing it up, until we had about 60 or 80 people on each of the ships.”

Sparrow balks at the intimidating odds and, after a ‘parley’ with Jones and Lord Beckett on a neutral beachhead, surrenders himself in order to infiltrate the *Flying Dutchman*. Locked in the Dutchman brig, Sparrow hallucinates a crowd of bad-tempered alter egos, including a rotted Jack fused into a bulkhead. Named Wyvern Jack, after a similarly cursed crewman in *Dead Man’s Chest*, the character was realized with Depp wearing iMocap tracking bands over his Sparrow garb while leaning up against a wall. Geoff Campbell’s team generated Wyvern Jack based on scans of Depp, and tracked and animated the digital character to the actor. “We stripped him down to an emaciated guy,” said Hal Hickel. “He was missing some parts, with his brain exposed. The tricky part was to make him look 900 years old, but still feel like Johnny. The eyes were what sold it, because they were terrific and that was where everyone was looking.” Verbinski conceived a mischievous detail for the scene, handing Depp a rubber brain supplied by propmaster Kris Peck. “Gore suggested Wyvern Jack reach back, pull the brain out of his head and play with it.”

Back on the *Black Pearl*, Tia Dalma conjures supernatural forces to assist the pirate fleet, using an incantation to cause a voodoo mixture in a bowl to ignite. Method created the fiery degeneration of objects in the bowl by tracking pyrotechnic elements to 3D objects in a 3D bowl and then combined 3D flames, smoke and ashes that appeared to float up into the shaman’s nose.

Tia Dalma transforms, her eyes changing color and her hair rippling as she grows to giant size. The production shot background plates for the scene on the deck of the ocean-going *Black Pearl*, with Naomie Harris standing up against the yardarm, then re-created the shot on a bluescreen stage, with Harris in the same pose, while the camera moved in and jibbed down, increasing her apparent stature in frame. ILM then combined bluescreen and background plates with a large physical effects rig, filmed in Palmdale, representing Tia Dalma at the peak of her transformation. “Tia Dalma grows into a 50-foot woman and then disintegrates into a zillion crabs,” related John Knoll. “Gore wanted the characters on the deck of the *Black Pearl* to get swept up and carried across the deck by all the crabs, and he wanted some good interactions, so he had the idea of using a ball pit — like in a child’s amusement park — to flood down across the deck.”

To stage the physical interaction, John Frazier’s team suspended nets above the *Black Pearl* set representing a large, vaguely human torso filled with 300,000 blue plastic balls. Effects technicians triggered the nets to open with squibs, sending the small blue spheres raining down onto actors, who struggled to wade against the flow. “It was a really impressive effect,” stated Knoll. “And it was a lot of fun! When it came time to shoot the gray and chrome sphere lighting references for those



In a wider shot, the Endeavour goes up in flames. Kerner Optical constructed a full miniature for the ship’s demise, and staged the scene in a water tank surrounded by greenscreen on its backlot slab. The Kerner pyrotechnic team choreographed events to extend the explosive impact of the Endeavour’s magazine destruction, toppling the remaining mast and triggering a series of further detonations that blew the ship apart. Visual effects supervisor Roger Guyett and director of miniature photography Carl Miller covered the scene with eight cameras running at high speeds.

shots, I dove into the pit and swam into the center. We ended up with some amusing pictures of me up to my neck in blue balls.” Blue-ball reference was not designed as a one-to-one exchange of spheres for crabs, but provided ILM with actor interaction and general dynamics of falling objects. “Any rigid simulation with more than a few thousand bodies becomes a big memory and computational problem. So, instead of calculating 300,000 collisions, we simulated a flow of crabs as particles. Our early tests looked promising — there were so many crabs, all moving so fast, it was difficult to see object intersections — and if we found a few crabs intersecting, we turned off those particles and added hero animated crabs, as needed.”

James Tooley’s team generated the crab motion based on a single creature model that Hal Hickel’s team equipped with leg-wriggling motion cycles. CG supervisor Michael Di Como’s team used particle simulations in Maya to create the crab flow, and assigned random behaviors to individual crabs. Animators then mixed in keyframe crabs. Jen Howard and her digital compositing team blended the crustacean avalanche to blue ball reference objects as the crabs flowed off the ship and spilled into the fluid simulation ocean.

Tia Dalma’s dissipation into the ocean causes the sea to churn and storm clouds to descend — initiating the climactic maelstrom and a sequence comprising more than 650 visual effects shots and approximately 20 minutes of screen time.

For wide establishing views of the ocean beginning to swirl, maelstrom compositing supervisor François Lambert integrated the first stage of ILM’s enormous fluid simulation into ocean plates filmed in the Caribbean. “The camera pans up and reveals something going on at the center of the ocean,” related Joakim Arnesson. “There are lightning flashes to signal something is going on as the fluid starts to spin, and that is where we see the maelstrom open up. We only used remnants of real ocean, seen fleetingly. Everything that happens after that was synthetic.”



Lord Beckett of the East India Trading Company walks dazedly toward the bow of the Endeavour as his ship is destroyed around him. The production photographed deck-level views of the scene on stage, where John Frazier’s physical effects team rigged a bluescreen set of the Endeavour’s deck, planting pyrotechnics into soft wood sections of the ship. Effects technicians used computer control to trigger multiple events as stunt performers portraying Beckett’s crewmembers reacted to the blast. Motion control covered the scene in repeat passes, with actor Tom Hollander filmed at high speed, walking through the frame with no flying timbers.

To create cloud formations twisting and forming into a cyclone that mirrored the vortex below, digital matte artist Paul Huston adapted a visual effects technique once favored by legendary matte artist Albert Whitlock. “Paul went back to a tried-and-true technique using cotton clouds,” commented John Knoll. “He sculpted a bunch of fiberfill into a nice cloudlike shape and shot still photographs of that. He loaded those stills into Zenviro, digitally cut them into separate pieces, layered them as different levels of sprites, and then added a twisting motion, combining 2D and 3D effects with a lot of matte-painted blending.” François Lambert layered cloud sprites against a digimatte sky cyclorama, describing a giant rotating disc of cloud with a mile-wide diameter.

To help guide the enormously technical process of generating digital ocean simulations, Verbinski met with the entire ILM maelstrom team — layout artists, effects personnel and composers — and outlined his artistic and dramatic requirements. “Gore had spent a lot of time trying to get the vibe of the maelstrom in his animatics,” said Knoll. “He had a coffee table book that contained a lot of pictures of violent stormy seas, and a surfing documentary, *Step Into Liquid*, which he liked as a target for the look of the water. But there was no whirlpool reference in nature that was meaningful, and that did pose a problem for us.”

To define maelstrom characteristics, freelance conceptual artist Yanick Dusseault produced digital renderings of the imagined storm. Meanwhile, ILM experimented with particle animation, physics-based modeling and fluid simulations derived from its partnership with Stanford University’s PhysBAM project. “We started generating wide views of the maelstrom using a large-scale structure like the spiral arms of a galaxy,” said Knoll, “but we soon found that we just couldn’t create enough detail in the foreground. We needed about four times the spatial resolution that we were getting. It was a big problem, and we really didn’t have time for this setback, but there wasn’t a whole lot of choice — Gore was not happy with the storm. So we had a crisis meeting to figure out how to create more resolution. Should we simulate very small sub-domains and figure out some way of stitching them together? How else could we optimize it?” The solution involved placing a bounding box around the whirlpool and flattening the vortex. “We transformed all the forces — bent gravity and bent the wind vectors — and then ran our simulation as a flat disc, which gave us much more spatial resolution. Then we warped that back into its original space. That was how we managed to achieve a sufficiently high level of detail.”

ILM created swirling whirlpool behavior by applying rotational forces to the fluid disc shape. “It took a couple of hundred frames to create the motion,” said Joakim Arnesson. “The forces then started to push out the water mass, which meant we had to compensate with forces pushing the fluid back in,



To place Beckett amid the mêlée, with myriad flying particles spiraling in slow motion through the air around him, Digital Domain rotoscoped Hollander, blended motion control passes and added digital flying wood chunks that appear to bounce off Beckett’s body. Digital artists created interactive flying splinters by generating a 3D version of the Endeavour set bombarded with rigid body simulations. Particles appeared to collide with surfaces of the set and with Beckett, bouncing and twirling through the air in slower motion than Beckett’s already dreamlike, slow-motion progression through frame.

otherwise everything would have spilled out of the domain. We then added Coriolis forces, wind, swirls, anything that made it look realistic.” The fluid simulation engine generated additional layers of detail as secondary simulations, creating splash, spray and mist. “We added a little jitter animation to every primary particle coming out of our particle engine. We then rendered those separately and applied them on top of our main water simulation. We rendered the water surface in a RenderMan RIB format, which allowed us to apply a surface shader on top. The surface was quite complex because it contained bubbles churning underneath, generated by our fluid engine. We generated foam mattes in another simulation, which we either mapped straight onto the surface or applied as projections to create areas of whitewater where splashes emitted. We had a lot of control over what the water could do.”

As the whirlpool forms, the *Black Pearl* and the *Flying Dutchman* break away from the pirate fleet and the *East India* armada and approach each other, cutting thick foamy wakes. All ships in the storm were digitally generated and used a custom animation rig that James Tooley’s team developed to make vessels float on top of maelstrom fluid simulations. Frank Losasso Petterson’s team created high-resolution wakes in a separate virtual domain that could then be integrated into larger water simulations to produce as much detail as possible.

The second stage of the maelstrom sequence involved shots inside the deepening pool, as ships opened fire on each other across the vortex. “It was a huge racetrack like the *Indy 500*,” noted Arnesson. “As the ships moved down deeper into the whirlpool, they went faster so they could gain speed and cut in on each other, catching up with the other ship.”

The majority of shots in the sequence included angles of the storm seen from decks of ships. Verbinski photographed foregrounds on gimbal rigs in Palmdale. ILM then generated backgrounds in the style of classic process shots. “The focus was on the foreground, with the maelstrom in the background,” stated John Knoll. “For those shots, it was not worth doing a custom ocean render for every shot. *Instead*, we created running footage as a background cyc to be used in as many shots as needed, like a live-action plate shoot for a car scene with greenscreen windows. We set up a bunch of camera angles to cover all our angles, and they became generic backgrounds that we used to put our shots together.”

The simulation team generated 14 angles with 90-degree fields of view of the interior of the maelstrom, vortex spin increasing as the ships descended until vessels were yardarm lengths apart. Asylum assisted with assembly of the sequence, handling precomps of selected shots. “We were already handling composites of bluescreen Dutchman characters,” said Phil Brennan. “So the production decided that it might be helpful for us to precomp the water into some of the shots that ILM was putting CG characters into. We layered ILM’s CG water into bluescreen plates of the deck of the ship in about 50 shots, and worked with John Knoll to get the correct look for the water with all the atmospheric effects they needed.”

ILM provided Asylum with backgrounds, mist and splash. Asylum then created bluescreen extractions, rotoscoped Palmdale plates, combined ocean views and returned the work to Eddie Pasquarello’s compositing team at ILM. François Lambert layered water elements and sky cyclorama, then added volumetric and atmospheric passes — spray, foam, bubbles, mist and depth haze — and integrated animated characters.

Final renders pushed the limits of ILM’s data capacity. “The simulation volumes were so high,” remarked Arnesson, “we had to run fluid simulations on 32 processors in parallel. A single scene wouldn’t fit in the memory of one machine. We had to divide shots up into 32 smaller chunks so each processor took care of one part of the domain, and then we combined everything at the end. We had the same problem with the particle engine. For secondary particle simulations, we were sometimes hitting 16 gigabytes of memory to simulate up to 20 million particles, which wouldn’t fit on our machines, so we had to divide it up.”

As the sequence progresses, the *Flying Dutchman* cuts in on the *Black Pearl*, riding faster, lower levels of the vortex. “We estimated that the ships averaged about 15 knots through the water,” observed Knoll.



Miniature mast extensions were a recurring visual effect used throughout the Pirates of the Caribbean trilogy to top full-scale representations of fictional sailing vessels built with only partial sails and rigging. Kerner Optical employed ILM matchmove data to photograph miniature mast extensions via motion control, aligning its miniature elements to animatics derived from production plates. Video lineups guided rough composites on the miniature stage. Compositors at ILM – and at other facilities – then blended miniature elements, which varied from full

“But the water was spinning quite fast, so in terms of the boats’ speeds through world space, we had them going pretty fast at times — sometimes more than 50 knots, or about 60 miles an hour.”

Ships clash masts and become entangled, allowing Dutchman crew to vault onto the Black Pearl. Verbinski shot stunt performers swinging across and landing in separate setups on the bluescreen stage. Swashbuckling action scenes in which Davy Jones engages Jack Sparrow in a climactic saber duel atop a yardarm in the storm featured stunt performers in iMocap gear. “Bill Nighy did all the acting and some of Davy’s sword fighting,” said Hal Hickel. “Bill’s stunt double, Tom DuPont, did scenes up on a big yardarm set on safety wires. Tom worked really hard to portray the Bill Nighy vibe in the way he moved, which was a big help to us in animating the scene. He also delivered Davy’s lines during the fight. We later shot coverage of Bill redoing the dialogue and used that as our main reference. In some cases, where Tom was being very physical in the plate, we superimposed a closeup of Bill delivering his lines in the corner of our footage, then studied both facial performances and mixed the two.” Davy’s duel with Jack was also a technical challenge to character rigging teams. “We had Davy in his great long pirate coat running around and fighting. It really pushed all our simulations to their limits, particularly as he spun around and his tentacles went flying.”

Facial tentacle simulations — one of the most complex aspects of the Davy Jones facial animation rig — were further complicated in shots following Sparrow’s slicing off the lower extremities of Jones’ beard. “The simulator that moved the tentacles was broken up into little joints,” stated Hickel. “James Tooley worked out a way to disconnect the joints below a certain point and then added a shape to make tentacles flat at their cut points. The simulator ignored everything below those cut points and made them move like the ends of the tentacles. We sliced three of them off and took a big nick out of a fourth.” To create effects of ink gushing from Davy’s severed tentacles, ILM filmed milk squirting over black and blended a negative image of the practical fluid with particle simulations in Sabre.

billowing sails to a few ratlines in the background of a shot.



As the saga draws to a conclusion, the Black Pearl returns to Tortuga, a pirate haunt established in the earlier films, where Barbossa takes his leave of Jack Sparrow. The production filmed the Black Pearl on the open water using the full-scale pirate ship hull built around a smaller, self-propelled vessel.



Kerner Optical shot a miniature element of the Black Pearl sails, aligned to the plate with complimentary lighting, while wind fans caused the sails to billow. CIS Hollywood then tracked masts and sails to the production plate and composited the elements.

Davy Jones meets his doom when Will Turner's sword pierces his disembodied heart. "We had a couple of special animatronic hearts that we would stab," commented Joel Harlow. "We used our silicone skin, from the animatronic heart that we'd made for *Pirates 2*, and wrapped that around a pig's heart. We plumbed that with blood tubes and made it gush as Orlando stabbed it." Nighy performed Jones' final moments in his iMocap costume on the Palmdale gimbal rig; then ILM animated his tumble into the fluid simulation ocean.

After Davy Jones' death, cannon fire from the Pearl blasts the Dutchman's mast away, separating the ships, and causing the Dutchman to sink. ILM compositor Kimberly Lashbrook assembled shots of the sinking ship by layering the CG vessel with high-resolution fluid simulations and particle simulations.

When the maelstrom dissipates, the *Flying Dutchman* resurfaces, shorn of encrustations, Will Turner at the helm. The makeup team depicted Bootstrap Bill and the other *Flying Dutchman* crew restored to human form by covering performers in a soup of slime and barnacles that gradually seeped away. For wide shots of the regenerated ship sailing alongside the Black Pearl, ILM integrated CG and miniature vessels into ocean plates filmed off Southern California. "We filmed the Black Pearl and two large wake boats," related John Knoll. "We set up choreography of the Pearl and the Dutchman coming together and attacking the Endeavour, choreographed that with the full-sized boats, and shot plates from camera boats and helicopters. The majority of our shots used those full-scale plates, and we added mast extensions and additional sails to the Black Pearl, which was not a complete replica. The restored Dutchman was computer generated in all its shots. For the Endeavour we used a couple of different scales of miniature."

The majority of Endeavour wide shots featured a 1/12-scale Kerner Optical miniature — a triple-deck square-rigger, redressed from the Dauntless in *Pirates 1* and patterned after the HMS Victory. For deck-level shots of the Endeavour receiving fire from the Dutchman and the Pearl, the physical effects team rigged a full-scale bluescreen set in Palmdale with extensive pyrotechnics. "I had guys working on that for months," said John Frazier. "It was all made out of balsa wood and the whole event was timed with motion control, synced to the computer." Stuntmen portraying Beckett's crew took strategic positions around the set and then reacted to the blast as ratchet-pulls hauled dummy cannons through frame and the effects team filled the atmosphere with pyrotechnic mayhem. "We hung bags of debris above the set and blew them up so it looked like cannon balls were going through sails and knocking down masts out of shot, creating all this debris raining down."

Image G motion control operator Mike Leben covered the event with cameras capturing repeat passes of stunts and explosions integrated with Beckett descending a flight of steps in catatonic disbelief as his ship is ripped to shreds. "We spent months working out all the physics of the destruction of Beckett's walk through his exploding ship," said Charlie Gibson. "We wanted to shoot the destruction at very high speed, close to 300 frames per second, with Beckett walking at a different frame rate. The lighting was extreme because of our high frame rates, so we had to shoot it at a deep stop. Tom Barron and the team at *Image G* did quite a bit of engineering to make all the motion control passes work together."

Tom Hollander performed the scene, filmed at 72 frames per second, walking through the set with no flying timbers in the shot. Digital Domain then layered the actor into the debris. "Our job was to

not only incorporate all the passes,” remarked Bryan Grill, “but to make it feel like Beckett was in the middle of the destruction. We did roto-capture of Tom Hollander and then added CG debris to make debris appear to shadow him and bounce off him.” Digital Domain CG supervisor Mårten Larsson implemented digital debris using a 3D version of the Endeavour set bombarded with rigid body simulations. Particles then appeared to interact with surfaces of the set and with Beckett as he progressed through shot. Flying wood fragments were simulated to bounce and fly about at 288 frames per second, twirling in midair. Rotoscope supervisor Vivien King then collaborated with Lou Pecora’s compositing team to intermingle live and digital elements in Nuke, including flying cannon balls, smoke trails and myriad wood shards.

Beckett witnesses the deck erupting before him as the Endeavour’s ammunition magazine detonates below. Kerner Optical staged the effect with a 36-foot-long, 1/3-scale version of the main part of the Endeavour deck that Geoff Heron’s team rigged with approximately 90 pyrotechnic events. “Carl Miller and I covered the setup with two cameras running at 150 frames a second,” explained Roger Guyett. “The whole event was over in 1.52 seconds real time, which gave us about nine seconds on screen. We spent a lot of time figuring out the pyro events to make sure it felt like the cannon fire was coming from both sides, as well as the explosions inside the ship. We had one static camera and another tracking sideways; and on the cut between the angles, we wanted two longboats on the deck to fly across the frame. We set a charge on the side of each, so one split in half and the other crashed into that, making a progression of destruction.”

Digital Domain layered the exploding deck with foreground elements of Beckett and his crew. ILM generated wide shots of Endeavour being blown to smithereens using a 1/6-scale miniature ship filmed in a 150-foot-long water tank on the Kerner Optical slab. “We built greenscreen walls around the tank so we could photograph the event from several different directions,” stated Guyett. “Carl Miller had eight cameras running on that, taking the ship through this *Bonnie and Clyde* moment. Partway through the explosion, we severed the last remaining mast at the front of the ship, which set off another really big bang that blew the ship apart, traveling up through the mast as it came down.”

Beckett meets his death in the explosion, leaving pirates free to pillage another day, and Will Turner to bid farewell to Elizabeth Swann before resuming his new duty as the captain of the *Flying Dutchman*. Verbinski filmed Turner and Swann’s romantic tryst — dubbed ‘Sex on the Beach’ — with Orlando Bloom, Keira Knightley and ILM on location in Hawaii. ILM integrated the *Flying Dutchman* into the background with digital matte paintings by Chris Stoski augmenting the idyllic setting. Method then created a subtle composite for a closeup of Swann’s face as she watches her lover on board the Dutchman returning to the immortal realm via a green flash. “It was technically a simple composite,” related Alex Frisch. “We added reflections in Keira’s eyes, some color treatments on her face and the background, but it was a difficult effect to create. Gore wanted to suggest the reflection of the green flash was somehow going to Elizabeth’s soul.”

The scene wrapped an epic adventure that thrilled audiences worldwide, revitalized a movie genre, and empowered a marathon filmmaking odyssey. “I had some time off between the first two *Pirates*,” reflected Charlie Gibson, “but since we started *Pirates 2* in the summer of 2004, it was a straight shot through to release in 2007. It has clearly been the biggest project that many of us have

ever been involved with, and it's been very dynamic! The movie has been changing, along with the nature of our work. Once we started to see bits of it come together, we realized that we needed other bits and other bits — and it grew exponentially from there.”

Advancements in visual effects technology grew in parallel with the show's demands. “You might think these water shows would become easier for us with every show we do,” commented Joakim Arnesson. “but it doesn't seem to work that way. I have worked on almost every water show at ILM since *The Perfect Storm*. We used some comparable technology to that, but we were also making use of faster computers with more memory, which allowed us to make simulations bigger and more detailed. We definitely pushed the limits this time, but I think our next show will be another step forward in rendering technology. Every project is different — and it never gets easier. It just looks better.”

The bold use of visual effects in all three *Pirates of the Caribbean* films was inspired by a thought process that began with the shape-shifting skeletons of the first film in the trilogy. “The only sensible way to shoot the effects was to treat them like they were any other part of the live-action,” concluded John Knoll. “The benefits of that were that all the performances happened on set, Gore could work with the actors in a way he was used to working, actors could play their performances off each other, camera operators could frame up, and the editor had a filmed performance to cut. The effects flowed seamlessly with the rest of the film because they were derived from action filmed on set. That was where the idea for iMocap came from. It gave us a higher level of performance than we ever would have achieved if we had tried to shoot characters three months later in a motion capture stage. The actors and the director were authoring the performance, so there was no stylistic break where the live-action ended and the visual effects began.”

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ARTICLE BY JODY DUNCAN

As comic book superheroes go, *Spider-Man* has been a largely wholesome one — not as squeaky clean as the original *Superman*, perhaps, but not plagued with the world-weariness lurking behind the mask of *Batman*, either. The casting of the earnest and sweet-faced Tobey Maguire as the arachnid hero in director Sam Raimi's *Spider-Man* and its sequel went a long way toward translating *Spider-Man*'s inherent decency to film.

In co-writing *Spider-Man 3* — with his brother Ivan and Alvin Sargent, based on comic book narratives by Steve Ditko and Stan Lee — Raimi opted to tell a darker story than he had offered in the previous two films, exploring a sinister change in Peter Parker's nature when he is infected with a symbiotic alien substance that attacks his system like a virus. While coping with uncharacteristically base and predatory instincts, *Spider-Man* also battles a trio of fantastic characters inspired by *Spider-Man* comic book lore: Sandman (Thomas Haden Church), Venom (Topher Grace), and Harry Osborn (James Franco), who dons a new Goblin guise to avenge the death of his father.

Though this new lineup of characters would require fresh designs and digital doubles created in updated pipelines at Sony Pictures Imageworks — the primary effects house for all three films in the franchise — the classic blue-and-red *Spider-Man* CG model that digital artist Koji Morihiko had built for the original *Spider-Man* held up, both technically and aesthetically, well enough to require only minute refinements. The design of the original *Spider-Man* suit and mask by costume designer James Acheson — built by Amalgamated Dynamics Incorporated in the first film, and fabricated by Frontline for *Spider-Man 3* — also remained virtually unchanged. "If there were any variations in the live-action costume, they were so minor that we didn't have to account for them in our CG model," said visual effects supervisor Scott Stokdyk who, after working closely with production visual effects supervisor John Dykstra on the first two films, flew solo on the third. "That meant we were able to reuse, seven years later, the classic *Spider-Man* that Koji had built, which is really amazing. Its musculature, skinning and surfacing properties were all the same. We have better tools now, of course; but Koji did such a fantastic job with that original model, it held up just fine, even all these years later."

Minor adjustments to the model included revising software to facilitate its interface with current versions of Maya, and adding user-friendly controls. "We updated the visible controls that animators use to grab on the character," stated Spencer Cook, who was promoted from a lead animator on *Spider-Man* to animation supervisor on *Spider-Man 3*. "With these visible controls, animators could just click on the character's wrist or torso or any other part of his body to move it around. That's not anything new — most rigs have that now — but it was new to this version of *Spider-Man*. We also updated the spine controls. We always had the option of using one of two spine configurations in the original rig, but we updated the switching controls. The forward spine rotates from the waist up, and the reverse spine rotates from the upper chest down. Depending on the action Spidey was doing, the animator could choose which spine to use."

From the first film, Sam Raimi's goal had been to ground the fantastic *Spider-Man* in the real, physical world, even in his CG form; and that philosophy was pushed to its ultimate limit for *Spider-Man 3*. "We gathered even more live-action reference during the shoot for this movie than we had on the last two films," stated Stokdyk. "We wanted to know, on a per-shot basis, exactly what the real character looked like in any given environment; and then we did everything we could to replicate that in our CG character."

In addition to aiming for photorealism in *Spider-Man*'s look, Imageworks explored ways to make the character's movements — as dramatic as they are — believable, as well. "In *Spider-Man* movies," said Cook, "we're adding an animated character into a real world — and we're always very aware that human beings are really good at perceiving body language and subtleties in that real world. Every person in the audience is an expert on human and animal motion; and so, we have to deal with the real physics of our animated character. We have to think about how far he can jump, how fast he should fall and things like that. Of course, there is a very real difference between real physics and movie physics; but, even though no real person could do what *Spider-Man* does, we wanted to make it believable within the context of the film."

To produce the most realistic, believable animation, visual effects plate leads John Schmidt and Gregory 'Nic' Nicholson developed a physics-based ballistics tool that enabled animators to check *Spider-Man*'s aerial swings and leaps against real-world physics. The physics tool determined, for example, how far *Spider-Man* should be able to swing, based on the speed at which he left a surface. "The acceleration and velocity a character has when he jumps off a surface is going to determine how far he can jump," Cook explained. "So we'd start by blocking out the animation of the jump, just keyframed, by hand. Then we'd use the physics tool to check if the distance he traveled and the speed at which he was traveling were realistic. The physics tool would look at the first frame of *Spider-Man* leaving the surface, and from that it would determine, 'If he is moving that quickly and with that much force when he leaves the surface, he can travel X amount of distance.' And if he was traveling a greater distance in our animation than he'd really be able to, based on the calculations in that initial frame, we'd increase his acceleration off the surface so he'd land where we wanted him to land.

"We didn't tie ourselves too rigidly to the physics tool, though. In these kinds of movies, if you animate action that is too realistic, it won't be dramatic and exciting enough. In the real world, a guy swinging from one skyscraper to another wouldn't look that interesting or dynamic. So the *Spider-Man* animation was a combination of eyeballing it and then using the physics tool to check our work. Most of what *Spider-Man* does is not physically possible for a human being anyway, so ultimately it came down to what we all thought looked good."

While the physics-based ballistics tool gave *Spider-Man*'s animation a basis in reality, his photorealistic look was based on information gathered on the Light Stage at the Institute of Creative Technologies at USC, an image-capturing system first employed by the visual effects team on *Spider-Man 2*. Rather than relying on sophisticated texture maps and shaders to simulate an actor's flesh on the digital double for that film's Doc Ock — played by Alfred Molina — Scott Stokdyk and John Dykstra had sought a system that would allow them to acquire textures of the actor's real skin, which could then be applied to the CG character and brought to life through artful lighting choices.

The Light Stage was just such a system, using four cameras, running at 60 frames per second, to photograph the actor's face as strobe lights synchronized to flash with each frame arced around him. Through this technique, the effects crew had been able to record hundreds of images of Molina per pass, which were subsequently projected onto cyberscan geometry, resulting in ultra-realistic skin textures in the Doc Ock digital double.

Since simulating realistic flesh tones had been the primary aim in that first Light Stage round, the effects artists had not subjected their fully masked-and-suited *Spider-Man* to the setup. For *Spider-Man 3*, they would. "This time," said Stokdyk, "instead of just using the Light Stage for our digital doubles of the actors, we put a person in the *Spider-Man* costume in the system, and used the resulting data to get really good reference of how the costume responded to light. So, as we lit shots for *Spider-Man 3*, we had a much better idea of exactly what the costume would do in lighting."

The Light Stage produced even better data than had been obtained for *Spider-Man 2*, due to incremental improvements in the system, such as an increase in the number of cameras from four to six, enabling crews to capture more angles and information with each pass. Also, because the crew would be creating digital doubles for all of the lead characters — rather than the one for *Spider-Man 2* — Imageworks set up an entire pipeline to streamline the application of the Light Stage data. "It was still a somewhat tedious task to convert all the information that we got on the Light Stage," related digital effects supervisor Peter Nofz, "but we came up with little finessing tricks to get that footage into our pipeline faster and to treat it uniformly. Even a tiny mistake in the pipeline could have disastrous consequences; and so we were very careful about setting it up and making sure that every character was treated similarly, ensuring we would get similar results at the end."



A deft story sense and an enthusiasm for Marvel Comics' *Spider-Man* character had helped director Sam Raimi to fashion two blockbuster films by the time he agreed to round out the franchise with *Spider-Man 3*. A darker film than its predecessors, *Spider-Man 3* explores a troubling change in the superhero's nature when he is infected with a symbiotic alien 'goo.' While coping with his emerging predatory instincts, the new black-suited *Spider-Man* (Tobey Maguire) also battles a trio of villains: *Venom* (Topher Grace), *Sandman* (Thomas Haden Church), and *Harry Osborn* (James Franco), who dons an updated *Goblin* guise to avenge the death of his father.

Imageworks' new lighting package, 'Katana,' also contributed significantly to building a better CG actor. "The feedback we had received from artists over the years about our previous in-house lighting tool was that it wasn't very user-friendly," said Nofz. "Everybody wanted a new lighting package that would allow the artist to work faster and more interactively. Katana also enabled us to reuse lighting setups, which meant artists didn't have to reinvent the wheel for every shot." This last feature was especially helpful in creating *Spider-Man 3*'s digital environments. "Artists could copy-and-paste an environment and get not just the building but also the building with the lighting. That could be done before, but it was difficult and time-consuming. Katana made that much easier, allowing us to push shots through much more quickly than ever before."

Although Katana and the improved Light Stage data resulted in photorealistic flesh tones on the CG actors, the effects team often projected the actors' real faces onto their digital doubles, particularly in tighter shots where Sam Raimi wanted the character's emotional state to read on screen. "Sam is very much an actor's director," explained Stokdyk, "and after the last movie, especially, it became clear that he was going to be most happy if he could direct the actors and get their real facial performances on screen, even in these CG actor stunt shots. So Sam would direct the actor through all the beats of the shot and get the real actor's face; and then we would use that photography as a face replacement element. We didn't do a face replacement for every shot, of course — we did our share of CG faces — but we tried to do them in key shots where Sam wanted to see the real actors. We always knew we had the backup of going all-CG if the live-action stuff didn't work out."

Visual effects plate supervisor Sheena Duggal supervised the face replacement elements, which involved shooting, with motion control, the actor performing appropriate facial expressions that were



Harry Osborn — in Goblin garb — chases Peter Parker through Manhattan alleyways aboard a high-tech glider. Visual effects supervisor Scott Stokdyk and his team at Sony Pictures Imageworks helped to realize the extended chase sequence by animating photorealistic digital doubles to perform spectacular aerobatics. Animators referenced footage of snowboarders to create Harry's glider action.



To ground the sequence in reality, crews shot actors performing some of the aerodynamics on bluescreen stages, utilizing sophisticated, computer-controlled wire

synchronized to the CG stunts. John Schmidt translated and imported previz files into a Camera Control Milo motion control system, ensuring synchronization of the stage and animated camera moves. “Sheena did an incredible amount of prep work for this motion control setup,” observed Stokdyk. “She worked with Spencer Cook and Sam Raimi to determine the eyeline for the CG characters at any moment in the shot, and translated that to marks for the actors to follow during the motion control shoot. This was sometimes achieved with tape on C-stands, or through the use of a handheld laser pointer.”

The precision and maneuverability of the wire rig and camera system engineered and operated by Go Stunts — a company that has done state-of-the-art flying work for movies and large-scaled productions in Las Vegas — facilitated the effects crew’s ability to replicate the dynamic moves in the previz animation on the motion control stage. “The stunt people, in the last two years, have advanced their wire work technology incredibly,” observed Stokdyk. “I think of it as motion control stunt wire work. Just as Spydercam has a really nice way of importing motion control camera information and using it to move a camera with great range, Go’s system has computer controlled high-speed winches that enable them to control, in a very precise way, how stunt people are flown around. Often on *Spider-Man 3*, they were able to manipulate and move the actors and the stunt people to match exactly what was in the previz. It was an incredible crossover between previz and stunt work — the closest we’ve ever worked with the stunt team on a *Spider-Man* movie.”

Even with the support of the Go Cam system, some of the stunts and camera moves devised in the previz were too extreme to be re-created for the purposes of shooting face replacements. “In those cases,” said Cook, “we’d take a shot all the way to a final animation, with Sam’s approval; and then John Schmidt and Nic Nicholson would take that information — the body animation and the camera animation — and translate it to a motion control rig and a rotating chair where the actor sat.”

“We did that for very specific face replacement shots, where there was no possible way to move the actor’s body relative to a fast-moving camera,” Stokdyk elaborated. “We’d just extract from our previz file the relative movement of the camera to the face of the actor, and capture the actor’s face motion control. Then we’d have the actor on a virtual card in the computer, and we could move that card around in 3D. This digital pin-blocking was a way to create convincing 3D moves that were achieved through 2D.”

rigs provided by Go Stunts, a company renowned for state-of-the-art flying work in movies and large-scale stage productions.



Harry flings Peter into a brick wall during the alley chase. Backgrounds were a mixture of Spydercam plate photography shot in downtown Los Angeles and Imageworks’ synthetic environments. The narrow configuration of the alley, both in the live-action plates and in the digital environments, heightened the sense of high speed in the chase. Imageworks dressed CG alleys with fire escapes, dumpsters and other items to provide ample opportunities for interaction between the characters and the environment. Imageworks artists also strove to replicate the high dynamic range look of the alley plate photography, which had areas with bright highlights, and others that dropped out to full black.

Years of experience and many improved tools and techniques enabled Imageworks to produce the most photorealistic digital doubles ever featured in a *Spider-Man* film; but, ultimately, the CG characters' success was due to the filmmakers' judicious use of them. "We still have a long way to go to produce a flawless human being in CG," admitted Peter Nofz, "but, on this movie, we had a much better feel for when to use a digital double and when not to. We didn't try to push the envelope, which is a lesson we learned on the last *Spider-Man*. The success of the digital doubles was all about using them in the right way."

Digital doubles for *Spider-Man* and model Gwen Stacy (Bryce Dallas Howard) appear in an early sequence in which a malfunctioning construction crane rips through a high-rise office building where a photo shoot is in progress. Sam Raimi accomplished the destruction sequence by blending live, miniature and digital elements. Live footage included Spydercam plate photography of the Alliance Capital building in New York — supervised by Sheena Duggal — and action shot on an interior office set that was built on the Sony lot by production designer J. Michael Riva and rigged to collapse by special effects supervisor John Frazier. The filmmakers intercut live-action with miniature photography of building and crane models built by New Deal Studios, and computer generated effects by CafeFX.

For an early establishing shot, CafeFX added a CG construction crane to the background of the New York location plate. "Then," observed CafeFX visual effects supervisor Scott Gordon, "for the next couple of shots, which are of an actor inside the crane cab, filmed on stage, we inserted 2½D backgrounds, stitched from tiles from the location that we mapped onto geometry. We also did a lot of reflection augmentation, adding reflections that should have been there in the glass building, but were not. We also got rid of reflections that were in the live-action, but shouldn't have been — such as the camera crew and equipment reflecting in the windows. We added smoke and other little things to sweeten the shots."

The sequence continues with a beam hanging from the crane smashing into the building, the action seen from three angles: one from the interior of the structure, shot on stage; one from the exterior, at the same height; and one from the ground level, looking up. "In the interior looking out," said Gordon, "you see Gwen diving toward camera as the beam knocks in right above her head. That was done with a couple of live plates, one with the beam coming in and destroying this breakaway set, and a second plate of Gwen making the dive. All we took from that second plate were Gwen and her reflections. We also integrated another plate of office workers running away into the destruction plate, along with the background out the window and CG breaking glass and smoke."



Sandman is born when Flint Marko stumbles into a particle physics experiment, his molecules dispersing into a sand pit and then re-coalescing into human form. The 'birth of Sandman' sequence featured a nearly 2,700-frame shot, the camera circling 360 degrees and rising from a macro view of agitated sand grains to a wider view of an amorphous, vaguely anthropomorphic figure. The sequence continues with the sand form evolving into a likeness of Thomas Haden Church. To create Sandman in his humanoid form, Imageworks character animators animated an underlying, bipedal model. Effects animators then overlaid that animation with layers of particle simulations.

The following cut to the outside featured the same action, with a CafeFX CG building exterior. “Again, we had the same pieces to put together,” stated Gordon. “We had plates of Gwen taking a dive, the crane coming through and destroying the interior, and people running. And then we added the office exterior to that, and mixed the plates. We also had to stitch tile backgrounds, extend the real beam, add a cable to the crane and add reflections.”

The third, street-level shot has the camera looking up 40 to 50 stories, near the top of the building, as debris rains down. CafeFX added CG debris, as well as the crane, to what was essentially a stock shot of the real building. “We also added a lot of reflections of debris,” commented Gordon. “Since this is a glass building, all of the raining debris had to be reflected in it.” The need to add so many desirable reflected elements, and to remove so many undesirable ones, often led CafeFX to entirely replace the building in the plate with its CG structure. “They had set up a descender rig on location, and they got a lot of background plates for us, traveling from roof to ground level, as if following the falling debris; but we wound up replacing a lot of those. Because the building was so reflective, sometimes it was just easier to re-create the move in CG, and get all the mattes we needed for reflections and so forth, than it was to use the live-action plate and paint out reflections on windows. A lot of the plates had camera cranes and equipment reflecting in them that shouldn’t have been there.”

The sequence continues with intercut exterior and interior views of the crane destruction of the building. One interior shot has Gwen sliding toward the edge of the collapsed floor, along with desks, chairs, pencils, garbage cans — all CG elements CafeFX added to the interior set footage. “As we fall toward the edge of the building,” said Gordon, “Gwen is yanked short because she’s grabbed onto a phone cord; but the rest of the debris continues to travel over the edge. Then we look down, and it’s like the view from the top of a cliff in a ‘Roadrunner’ cartoon — it’s a long, long way down. It’s a really dynamic shot that starts on her and then continues over the edge of the building. For that, we had the same live-action stage elements, mixed with a CG hero building and a pan-and-tile background and street below. The pan-and-tile backgrounds were still frames; but they wanted moving cars in these shots, so we stole cars from other moving plates and put them in the pan-and-tile backgrounds. We also cut out some of the cars that were in the stills and animated them. We did a little bit of everything to bring life to the shots.”

For subsequent shots of office debris hitting the street below, production had photographed actors standing on location, reacting to imaginary falling detritus; but ill-timed reactions by the performers required that CafeFX rework the action, in addition to adding CG debris. “It looked like the actors were cued a little late,” noted Gordon, “so we had to paint out a couple of guys who were standing there and didn’t move when the camera started moving.” To add excitement to the shots and improve timings, CafeFX also tweaked physical effects gags shot on location — a hot dog cart flipping into the air; a foreground person ratcheted backward, as if hit by a large chunk of debris — and replaced a taxi sitting on the street, its roof caved in by a fallen desk, with a CG taxi, animating a CG desk to fall onto it.

Shots of the crane actually ripping through the building — first horizontally, then vertically — combined CafeFX digital effects with New Deal Studios miniature photography and Spydercam plates shot on location. “They had shot these moving plates,” stated New Deal supervisor Ian

Hunter, “going over this building, looking down at it, imagining that the crane was ripping through it; and we had to match to that with our miniature photography. Normally, we would shoot something like this locked off and high speed. But in this case, because we were matching two plates with moving cameras — as well as a live-action set piece that had to be sandwiched into the miniature plate — we had to do motion control at high speed, which presented some real challenges. We had to control the motion of the crane, because the crane’s action going through the floors of the building had to be synced up to where the camera was in the shot. In order to do that, we built the crane on a motion control base that used hydraulic rams, which could then be controlled by our Kuper motion control system.”

New Deal’s 1/6-scale miniature crane, engineered by Scott Beverly, measured 42 feet long. “Most of it was made up of rock-and-roll truss,” said Hunter. “And then, at the end, there was a 13-foot length of steel that had all the rollers and cables and things you see on a construction crane. That was our business end of the crane, the part that could literally rip through the miniature building.”



Prior to his transformation into the black-suited character, classic red-and-blue Spider-Man rescues model Gwen Stacy (Bryce Dallas Howard) from the unscheduled demolition of a high-rise building by a malfunctioning construction crane. The sequence required artful blending and intercutting of exterior location plate photography, footage shot on a full-size collapsing office set rigged by John Frazier and his special effects crew, miniature photography executed by New Deal Studios, and digital effects created by CafeFX.



In the final composite, CafeFX – under the supervision of Scott Gordon – added New York City plate photography into the blue matte areas surrounding the special-effects-rigged office set where Howard and other actors had feigned running from the swinging construction crane.

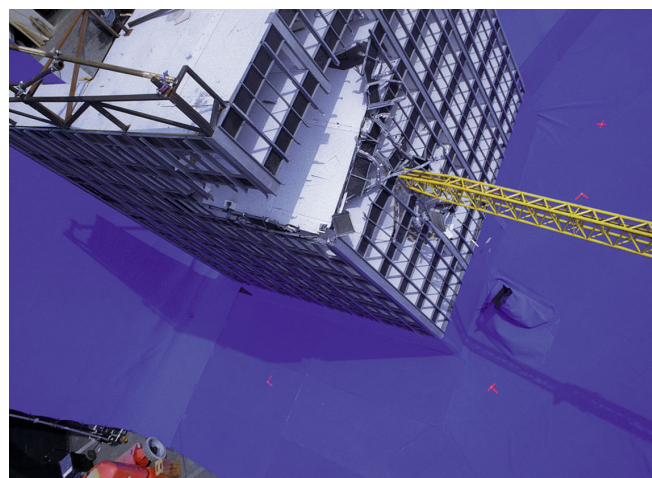
CafeFX also inserted a computer generated crane, replicating the machinery seen in the live-action and the miniature version built and shot by New Deal.

Built under the supervision of Forest Fischer, the 1/6-scale building miniature stood 25 feet tall and consisted of a steel frame — with slots cut out in the appropriate places to allow the crane to pass through — covered with laser-cut medium-density-fiberboard walls. “Where the break was supposed to be,” Hunter remarked, “we used black foamcore that was laser-cut to match all the window openings. Those pieces could be screwed on wherever the crane was going to go, so the crane would have a weak material to pass through.” New Deal used a soft aluminum to create window frames that would bend and crumple with the impact of the miniature crane, but left the windows themselves open and glass-less, as requested by production. “We had intended to put glass in all the windows and shatter them as the crane went through. But somewhere along the way, production became concerned that because they were going to be putting our model into plates from New York, reflections were going to be an issue. So it was decided, near the end of our construction schedule, not to put any glass in. The window areas were just left open, and CafeFX added digital glass afterward.”

With the miniature building and crane set up in the New Deal parking lot, director of photography Tim Angulo and operator Josh Kushner filmed the first shot of the crane approaching the building, then swiping through it sideways, using Pacific Motion’s Gazelle motion control camera. “That camera is used a lot in live-action,” remarked Hunter, “and it can travel down the track at a pretty good clip. We shot it at 60 frames per second, having to be frame-accurate with the camera at that high speed. On top of that, we had to marry the live-action shot of the rigged floor dropping to our miniature, which meant we had to have our miniature floor drop at the same rate that the live-action floor dropped, and at a very specific point in the move. The floor itself was on



In the New Deal Studios parking lot, crewmembers prepare to shoot their high-rise miniature, featured in exterior views of the crane sweeping through the structure – first, horizontally, then vertically. The building miniature measured 25 feet tall and consisted of a steel frame covered with medium-density fiberboard walls. New Deal cut slots in the steel frame and inserted lightweight foamcore to enable the miniature crane to pass through predesignated points. Soft aluminum window frames bent with the impact of the miniature crane – but window openings were left glass-less to avoid unwanted reflections. CafeFX added digital glass to the miniature building in postproduction.



another hydraulic ram, with a trigger switch on the floor below; so as the crane went through, it literally hit this switch, which caused the floor to drop. Then, once the floor dropped, the camera kept advancing so that it lined up with the live-action plate.

Fortunately, Sony tracked the live-action plate so we could tell frame by frame where we needed to be with each element of the shot.”

CafeFX augmented and reworked New Deal's miniature photography to accommodate significant changes in the action as the sequence evolved in editorial. “The cut was still very much in flux at the time New Deal shot the miniature,” stated Gordon. “Because of that, the miniature and the live-action didn't match up exactly when the sequence came together in its final form. We ended up creating new shots out of the old elements by re-timing and reprojecting everything. As a result, there's quite a lot of CG in the final shot of the crane going through the building. The building in that shot is actually a CG building, with the miniature photography re-timed and reprojected onto it. All of the glass on the building is CG; and much of the debris is CG, as well. What we got from the miniature on the first shot were beam impacts on some of the interiors, and the crane — although we even extended the crane a bit in CG.”

The sequence continues with a high exterior view of the crane rising vertically through the building, toward camera, taking out floor after floor. New Deal reset its foamcore pieces into the building miniature frame's precut slots for the vertical move. “We unscrewed the destroyed foamcore pieces,” said Hunter, “removed the previous take's broken floors, and put in a new set of floors and walls made of urethane foam covered in plaster, as well as individual, laser-cut, drop-ceiling panels.” New Deal also dressed the interiors of the miniature for the vertical shot. “We knew that as the crane passed through, it would expose some of the interior. So about four feet on either side of where the crane passed, we put in desks and chairs and little keyboards. We also put a few miniature spark hits on the floors so it would look like electrical conduits were being broken by the crane.”

The crew again used a motion control setup to shoot the crane's rise through the building, following the path as determined and extracted from previz files. “For this shot,” said Hunter, “we went with a different camera system, called the Graphlight, which has a really long boom. We mounted that on a 20-foot-tall scaffold; so we really maxed out the height of the rig in order to get the camera high enough over the crane and building. Again, we had to match up with the Spydercam shots. Sony gave us tracking data to drive the camera head so it would line up to their plate.” Once New Deal completed photography on the building destruction, the crew laid the model on the stage floor and shot a motion control pass as a background for a shot of *Spider-Man* descending through the debris, racing to catch Gwen Stacy as she falls from the destroyed building's upper stories.

CafeFX augmented and reworked New Deal's miniature photography to accommodate significant changes in the action as the sequence evolved in editorial. “The cut was still very much in flux at the time New Deal shot the miniature,” stated Gordon. “Because of that, the miniature and the live-action didn't match up exactly when the sequence came together in its final form. We ended up creating new shots out of the old elements by re-timing and reprojecting everything. As a result, there's quite a lot of CG in the final shot of the crane going through the building. The building in that shot is actually a CG building, with the miniature photography re-timed and reprojected onto it. All of the glass on the building is CG; and much of the debris is CG, as well. What we got from the miniature on the first shot were beam impacts on some of the interiors, and the crane — although we even extended the crane a bit in CG.”

More of the miniature photography was usable in the second shot of the crane rising upwards through the building. “The exposed floor is there,” observed Gordon, “and that was all miniature — really nicely interactive as the crane rips through the exposed floor. That is tucked into the middle of another all-CG, reprojected, re-timed shot. There is also a little digital Gwen hanging outside the

building that was done by Sony Imageworks and supplied to us. As the crane comes sweeping up through the floors, it hits the beam she's hanging on, and knocks her off — so she's falling, and then *Spider-Man* comes along and saves the day.”

Since the *Spider-Man* who catches Gwen's fall would be the animated character, stunt crews rigged Bryce Dallas Howard — who performed the stunt of falling, then being swept along the street — with a series of cables and ropes. “The shot of Gwen swinging to the street at the end of the sequence was one of the largest rig removals we've ever had to do,” commented Gordon. “There were probably eight ropes on her, as well as shadows from the ropes. We did months' worth of paint work to get rid of all of those things in the shot.”

While the rescue of Gwen Stacy is business as usual for *Spider-Man*, his life becomes more complicated when one-time friend and roommate Harry Osborn — determined to exact revenge for the death of his father — appears wearing a more hip version of Norman Osborn's Green Goblin disguise. James Acheson designed the goblin costume, which was built by Frontline. It is this costumed version of Harry that, early in the film, engages Peter Parker — in his street clothes — in a chase through narrow New York alleys.

From the beginning, Raimi and the visual effects team marked the harrowing alley chase as a visual-effects-heavy sequence that would feature synthetic environments and digital doubles for Peter and Harry — particularly in the most dynamic shots of the character aboard his ‘sky stick,’ a high-tech, snowboard-like glider. “Part of the concept with this new Harry character was that he uses very modern, sophisticated technology,” said Scott Stokdyk, “such as the technology in his glider, which was meant to be much more impressive and maneuverable than the glider Norman Osborn had in the first *Spider-Man*. Not only does Harry use the glider for transportation — with really cool, snowboard-like moves — he also uses it as a weapon, doing martial-arts-style moves on it. Spencer Cook and the previz team did a lot of animation tests to figure out how Harry could come flying in on this thing, turn on a dime, and then use it as a weapon in combat.”

To create CG Harry's moves on the glider, Cook's animation team — led by Bernd Angerer — referenced footage of extreme snowboarders in action. “We had tons of reference of snowboarders that we looked at,” remarked Cook. “We had reference of them jumping up in the air, twisting and flipping, and we used a lot of those kinds of moves for Harry on his sky stick. We also looked at skateboarding reference. Then we re-created a lot of those snowboard and skateboard moves in our animation.”

Some shots, particularly those that started wide and moved to medium or close range, blended the animated Harry with bluescreen elements of James Franco on Go's wire rigs. For this sequence and others, the visual effects artists were able to use a lot of the Harry bluescreen elements in their shots, since Franco proved exceptionally adept at the wire-gymnastics. “James was really great at working with this sky stick on the bluescreen stage,” said Stokdyk. “Sometimes, he was better at it than the stunt



Sandman's size grows when he emerges from a dump truck filled with sand, where he has hidden to evade

people. There were times where we thought we would use a stunt person, because it was a wide shot, for example, and the character would be fairly small in frame; but the body language and motion were so much better with James Franco, we ended up using him, even in those wide shots. He was fantastic at it.”

police. Raimi and his team conceived Sandman as a shape-shifting character who could collapse and slip into small spaces, blow about like a cloud, or expand to monstrous size. Increases in Sandman’s mass were always justified in the story by the character’s access to a nearby sand source – in a dump truck, on a beach, or in a construction yard.

The alley sequence also featured a digital double for Peter Parker performing *Spider-Man* aerial acrobatics — a first for a *Spider-Man* film. “We hadn’t had to build a complete Peter Parker digital actor for the previous films,” stated Stokdyk. “On the first *Spider-Man* we saw a little bit of Tobey’s face inside the homemade costume for two shots; and on *Spider-Man 2*, we had a shot of *Spider-Man* in the costume, but with the mask off, so we saw Tobey’s face. That was a hybrid of our classic Spidey, with Peter Parker’s head on it. But we never had to do a full street-clothes version of Peter digitally, with cloth and hair and skin on his hands and arms.”

Imageworks employed Syflex to simulate Peter Parker’s clothing. “We decided that Syflex would be the best choice,” said CG supervisor Bob Winter, “and it turned out to be a very nice tool. We had a lot fewer cloth problems this time than we’d had with *Doc Ock*. Of course, part of the problem with *Doc Ock* was that he was such a complicated character, with all those many arms and his big coat flapping around. Peter Parker in his street clothes was, in many ways, a much easier thing to create than *Doc Ock*.”

Depending on the shot, digital doubles for Harry and Peter employed either animated facial performances, or photographic face replacement elements tracked to the CG characters. In some cases, Imageworks animated the Peter Parker double by applying facial capture data of Tobey Maguire the team had gathered on *Spider-Man 2*. The crew also used Light Stage data from the previous film to create realistic lighting and flesh tones on the CG actor.

Backgrounds for the alley chase were a mixture of Spydercam plate photography shot in Los Angeles alleys and synthetic environments by Imageworks. The narrow configuration of the alley, both in the live-action plates and in the digital environments, heightened the sense of speed in the chase as Harry flew by on his glider and Peter performed classic *Spider-Man* leaps and swings. “Because the alley was so narrow,” noted Stokdyk, “we had a lot of opportunities for interaction between the characters and fire escapes and trash cans and dumpsters and other props you would find in alleys; so we dressed our environments with a lot of that type of thing.

“We also wetted the ground in the alley to give us some interesting highlights. In all of our digital environments, we went for a high dynamic range



Spider-Man joins the police pursuit of Sandman, webbing himself to a speeding armored car and ‘skiing’ down the street aboard a dislodged vehicle door. Though seven years had passed – a significant time period in the realm of digital technology – the classic blue-and-red Spider-Man CG model that Imageworks digital artist Koji Morihiko had built for the original Spider-Man held up, both technically and aesthetically, well enough to require only minute refinements for Spider-Man 3. Minor adjustments to the model included revising software to facilitate its interface

feel, with a lot of highlights, as well as rich, dark areas that dropped out like real photography would.

with current versions of Maya, and adding more user-friendly controls.

In the real Spydercam plates we'd shot in Los

Angeles, we saw that some areas dropped to full black, where there was no information on the film; and so we tried to capture that same look in our CG alleys."

In addition to building 15 CG structures for the alley backgrounds, Imageworks created another 15 skyscrapers to use in conjunction with the digital New York cityscapes it had been modeling and assembling into a massive library since the first *Spider-Man*. "Every show," commented Stokdyk, "our digital environments get better, and we get better at knowing where we need detail and where we don't. So we built quite a few new buildings for *Spider-Man 3*; and since those were our highest-quality buildings, we put them in the foreground. We had the *Spider-Man 3* buildings front and center, the *Spider-Man 2* buildings behind those, and the *Spider-Man 1* buildings behind those." CG supervisor Grant Anderson and lighting lead Andrew Nawrot oversaw the digital building construction, with Elbert Yen working as the primary texture painter.

Throughout the alley chase — even in the CG-heavy middle section — Imageworks blended photographic elements into its CG alley environments whenever possible. "We've always felt it's a good idea to mix in a little bit of real photography, even in the middle of a CG shot," remarked Peter Nofz. "It keeps the shot grounded, and keeps us clear on what our CG stuff needs to look like. That was something we'd learned on the first *Spider-Man* — to always inject a little bit of plate into these big digital sequences."

The alley chase ends when Peter returns fire with one of Harry's pumpkin bombs — winged mechanical weapons created digitally by Imageworks — and the smoke emanating from the bomb causes Harry to crash his glider.

Later in the movie, Harry and Peter engage in hand-to-hand combat at the Osborn estate, which ends with Harry's being disfigured in a pumpkin bomb explosion. The Peter Parker in this fight is a far different character than the one Harry chased in the alleyway, having fallen under the dark influence of an alien symbiotic organism. The organism — dubbed 'black goo' by the visual effects team — crashes to earth on a meteor, not far from where Peter and Mary Jane (Kirsten Dunst) are enjoying a romantic interlude in a treetop web. John Frazier's crew engineered a practical explosion at the Disney Ranch to simulate the meteor's crash landing, and generated practical smoke rising from a prop meteor for a subsequent closeup of the impact site.



Spider-Man — convinced that Flint Marko is the killer of his Uncle Ben — confronts the molecularly altered character, driving his fist through Sandman's midsection. To guide effects animators in creating their particle sand effects, Scott Stokdyk and his team conducted a series of tests with real sand. John Frazier and his crew devised special effects gags, manipulating the sand to create behaviors illustrated in the storyboards — such as blowing and swirling — and director of photography Bill Pope shot the sand effects against black. Imageworks then scanned that film photography and matched it digitally.

Imageworks then added the CG black goo to the shot, as well as additional layers of CG smoke.

At Imageworks, CG supervisor Dave Seager oversaw look development of the CG black venom, first conceptualized in drawings by concept artist E.J. Krisor, a major contributor to *Spider-Man 3*. “He did some amazing drawings for us, and that’s what we used as the basis for what the goo should look like,” said Peter Nofz. Once the look was established, Ryan Laney developed the technology for producing the organism, while Koji Morihoro was instrumental in its animation. “It was a pretty complicated pipeline, because it was one of those crossovers between pure hand animation in Maya and procedural animation in Houdini. It needed the attention of hand animation because it had to look just so; but there was so much of it, we had to use a certain amount of procedural animation, too. So we put a team of technically strong character animators together with a team of really strong effects artists; and between the two teams, they came up with this goo and how it would behave and move.”

The symbiotic goo clings to the back of Peter’s motorcycle as he and Mary Jane leave their romantic spot. It then enters his apartment, adheres to his suit, and, eventually, spreads throughout his limbs and torso in inky black tendrils — an invasion Peter experiences in a dream. The shot of Peter’s body being consumed by the black goo evolved out of one of Imageworks’ earliest test shots. “Everybody just fell in love with that test shot,” remarked Nofz. “In fact, everybody loved it so much, it wound up in the trailer and in the movie.”

Peter awakens to discover that his blue-and-red *Spider-Man* suit has turned a sinister black. Frontline crafted the black suit from a James Acheson design, creating a raised webbing pattern that would catch highlights, making it read better in dark environments. This was particularly crucial, as *Spider-Man 3* — unlike the previous two films — was set primarily at night. “Lighting the black-suited *Spider-Man* so that he would show up at night, over a black sky, was just as hard as it sounds,” said Scott Stokdyk. Imageworks took its lighting cues from the way director of photography Bill Pope lit the actor in the dark suit on the set. “We noticed that Bill used a palette of warm lights on one side and cooler lights on the other side; and the costume picked up a lot of great highlights and colors from the colored lights in those environments. We found that we were able to set our black-suited Spidey apart from a dark environment by mimicking in CG the colored lights that Bill Pope had used on set.”

As designed by Acheson, the new *Spider-Man* is roughly ten percent bigger than classic *Spider-Man*, especially in the shoulders and thighs, requiring padding in the practical suit and a beefed-up CG model for shots that could not be achieved in camera. “Because of the difference in size,” noted Stokdyk, “we scanned a new model for the black-suited *Spider-Man*; but we still applied a lot of the work that Koji Morihoro had done on the original to that new model.”

Early in production, Spencer Cook and Sam Raimi engaged in conversations as to how the black-suited *Spider-Man*’s more powerful physique and darker nature would be reflected in his animation. “We wanted to make sure that everybody perceived this as the same person,” said Cook, “but with an altered personality. A lot of conversations I had with Sam in the beginning were about how we would display this different persona through body language. We came up with ways to exaggerate his poses. We made him faster. The way he swings is rougher and more reckless, as if he doesn’t

care as much about his personal safety. He does bigger leaps and long swings, shooting the web at the very last second before he hits the ground.”

This darker version of *Spider-Man* pits himself against Sandman and Venom, two of the most popular villains from the original comic books. The former arises when career criminal Flint Marko (Thomas Haden Church), chased by the police, enters a remote area where the military is conducting a particle physics experiment on a mound of sand. Stumbling into the path of the particle test, Marko is atomized, his molecules dispersing into a sand pit and then re-coalescing to create a human form. A shape-shifter, Sandman can control the sand within his body to form a hard fist, or collapse and slither, snake-like, into small spaces, or expand to monstrous proportions.

Creating this Sandman — illustrated in its variety of forms by E.J. Krisor — was the most challenging effects task of the show for the team at Imageworks. “Sandman and all the sand effects were the hardest things to do, took the longest time to develop, and took the longest time to do per shot,” admitted Scott Stokdyk. “Part of the challenge was that there were so many different types of sand shots. There were shots of sand falling and spraying, shots of Sandman looking more or less human, shots of Sandman as a 10-foot-tall creature, and shots of Sandman as a 100-foot-tall monster. We had shots of a wet, mud-man Sandman, and Sandman dissolving and flying away through the city in a cloud of sand. There were many, many Sandman forms. As soon as we saw the storyboards and the concept art for Sandman, we knew it was going to be the biggest combination character-and-effects challenge we’d had at Imageworks since our transforming human in *Hollow Man*.”

Stokdyk, sand effects supervisor Doug Bloom and effects R&D lead Jon Cohen started the Sandman project by breaking down the storyboards to determine all the different types of sand effects that would be required. The visual effects team also conducted a series of tests with real sand — gags that were rigged by John Frazier and shot by Bill Pope. “We shot all these different types of sand behaviors,” said Stokdyk, “like blowing sand, falling sand, sliding sand — anything we could think of that was related to the early boards. Then the team took that film photography and scanned it in and matched it in CG. That was our first proof-of-concept test: shooting real sand doing all these behaviors against black, and then exactly replicating that photography in CG.”

To create Sandman in his humanoid form, Imageworks character animators animated an underlying, bipedal model; and then effects animators overlaid that animation with layers of particle simulations. “The character animation team worked very closely with the effects animation guys



High above the city, black-suited Spider-Man contemplates the increased power bestowed on him by the alien goo. Frontline constructed the black Spider-Man suit from a James Acheson design, creating a raised webbing pattern that caught highlights, making it read better in the movie’s many nighttime shots. Imageworks re-created the effect in its digital double, taking cues from Bill Pope’s on-set lighting to highlight the dark character with glints of warm colors. Due to the black-suited Spider-Man’s increased size, Imageworks scanned a new model – but still applied much of the character rigging from the original CG Spider-Man.

to make sure that the effects animation of the sand was part of his character, as well,” Spencer Cook remarked. “Sometimes we would animate spheres as part of the character animation, just to give the effects guys a guide.”

Digital effects supervisor Ken Hahn, who joined the *Spider-Man 3* team late in the game, after finishing his work on *Ghost Rider*, had suggested adding the spheres — what he called ‘eggs’ — as a means to better represent what the final animation would be when a Sandman shot was still in its character animation stage, without the layers of particle animation. “We had to have something in the character animation to help us figure out the timing and volume aspects of these simulations,” Hahn related. “So, to show parts of Sandman collapsing and whatnot, they put in these little sphere representations of various sizes. For sand sheeting off they’d put a sphere egg falling from one part of the body to the ground; for sand shifting from one place to another, they’d show eggs moving from one part of the body to another. This was just to block it out, get all the timings, and figure out how much of the character we should be seeing in a particular frame. The first time I saw it, it looked very odd and funky; but it allowed us to show Sam roughly what the final animation, with the particle stuff, was going to be, before we took all the time to actually run the simulations and show a more accurate representation. That way, he could at least start directing the animation guys before we went to all the time and effort of the simulation.”

Only after this initial character animation was completed and approved did the effects animators begin to add the particle simulations, increasing their complexity incrementally. “We did a very simple thing first,” explained Hahn, “which was to populate the actual meshes coming out of the animation with a surface treatment of particles moving around, rather than a volume treatment. Then we’d start to see particles with the mesh, with the eggs swimming about and moving and shifting, and it gave it more life — it wasn’t just a rigid, enveloped character. As that became more refined, we started getting into the volume aspects.”

Though Sandman changes form throughout the film, appearing sometimes as an all-CG character, sometimes as the live-action Thomas Haden Church, and sometimes as a combination of the two — with specific areas of his body made of sand — Church’s performance always drove and informed the character’s animation. “Any time we shot anything that was a sand effects shot,” noted Cook, “we would put two high-definition witness cameras on Thomas in the scene, in addition to the film cameras, so we could use all of those angles to animate the character. And if the original photography didn’t have Thomas Haden Church in it, we shot video sessions of him to base the animation on. I also shot video reference of one of our animators, Scott Fritts, when Sam wanted to change the performance and Thomas wasn’t available.”



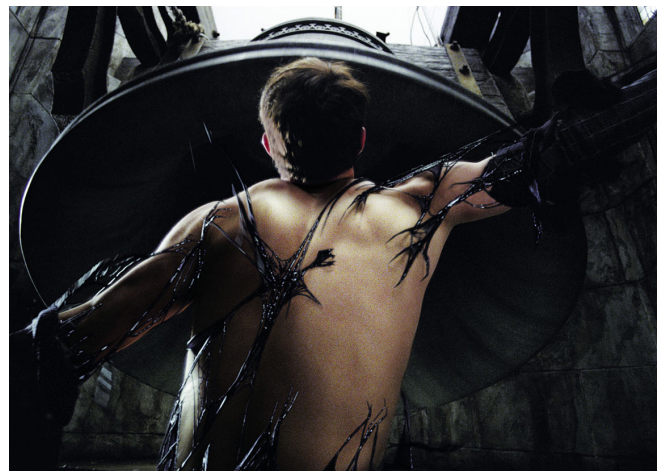
The black-suited Spider-Man engages Sandman in a brutal fight within New York’s subway system. At one point in the battle, Spider-Man pushes Sandman against a passing train, which causes his sand-filled head to be shaved off, layer by layer. Crews filmed Thomas Haden Church as a stunt Spider-Man pushed his head against a vibrating sheet of plexiglass, providing Imageworks artists with real-world lighting and physical interaction on the character. In postproduction, Imageworks tracked its digital head to Church’s body in the plate, and executed a CG erosion effect on it, complete with flying sand particles.

In addition to capturing Church's performance with high-definition cameras, the team arranged a facial capture session with the actor, conducted by motion capture supervisor Remington Scott. "We put dots on his face and captured him going through a range of expressions," said Cook. "We also did that with James Franco, and with Topher Grace, to some extent; and we already had facial capture for Tobey from the last movie. We used it a bit for those characters; but we did more face replacements with those guys. We used the facial capture more with Sandman because we wanted to introduce aspects of Thomas Haden Church's facial expression, even when he was made entirely of sand and didn't look that much like him. We wound up incorporating a lot of his expressions — grimaces and angry expressions and things like that. Thomas was very expressive and cooperative during the facial capture session, so we had this whole library of great expressions to choose from. We used that data to animate Sandman in a lot of shots."

For the scene in which Marko enters the testing area and is atomized, Bill Pope shot exteriors at Disney Ranch, as well as on a Sony stage set featuring a sand pit forty feet across. John Frazier and his crew set up a spinning light rig on the set, which served both as a prop representing the atomizing device and as a real-world lighting source. "We had discussed doing that CG," said Stokdyk, "but we realized that we needed to light up everything, including the actors, in an accurate way. It really helped to have a real light source there. Then we added an incredible amount of sand effects to this footage, including an effect of Thomas dissolving away to nothing. We had our HD witness cameras at different angles on the set, and that enabled us to go in and match a 3D character to the actor. Based on that, we generated 3D layers for erosion of the body, with particles flying off."

The atomization scene then transitions to the 'birth of Sandman' sequence, supervised by Ken Hahn and Bob Winter, with Bernd Angerer serving as lead animator. As blocked out in previz of the pivotal scene — created by Spencer Cook early in production — the birth of Sandman starts with an extreme closeup view of sand grains. "All we see is a macro image of about a dozen sand grains," said Hahn, "but, up that close, you can't tell that they are grains of sand. They look like rocks; and then they become agitated, rolling over on themselves. The camera does a slow pan, following them as they start joining together. As the camera keeps panning around 360 degrees, it also gets a bit of elevation, and you see trails of sand grains, congregating in a central area."

The effects crew referred to the coalescing sand as 'smart grains,' denoting a level of consciousness. "The smart grains form a head and shoulders that start to emerge out of this mound of sand," Hahn continued, "but because this collective consciousness hasn't quite gotten its act together, the statue of sand breaks apart and collapses. This whole beginning of the sequence is a very long, slow shot — 2,672 frames — and there's no dialogue or anything else to focus on except the sand. Because of that, we tried very hard to make it look visually



Disturbed by his merciless behavior during the subway fight with Sandman, an anguished Spider-Man goes to a

interesting and complex, and to sell some sort of story arc within this one long shot.”

The sequence continues with the sand again trying to will itself into a human form. “All the sand comes rushing together and starts forming a human shape,” said Hahn, “but this time the form is much clearer. It is not so amorphous or ill-defined. It starts looking like a real character with arms and musculature and a face you can start reading. You can’t tell it is Thomas Haden Church yet, but it is a face. As the camera continues to spin around him, he is able to raise an arm and undefined hand. He looks at that big mitt and realizes that he’s not really human, that he has become something else. At the very end of the shot, the camera winds up close on his face and you see this awareness of ‘What have I become?’ He is conscious, but he’s evolved into something else.”

The birth of Sandman ends with the character — as Thomas Haden Church — striding powerfully out of the sand pit. “I emphasized ‘bookend poses’ for the beginning and end of the sequence,” remarked Cook. “In the first shot, Sandman is weak and pitiful; but in the last shot, he is strong and determined. And then, all the shots in between show the progression of the character from one extreme to the other.”

Illustrating that progression, with multiple transitions from one type of sand effect to another, was an extremely difficult technical feat. “The technical side of this sequence was rather painful,” Hahn admitted, “partly because of all the transitions, even within the first 2,672-frame shot. The large sand grains seen in the first macro view were hand animated; then we had to hook in from that hand animation into our particle animation as the camera pulled back, transitioning from modeled hero grains of sand, to RenderMan curve primitives, to RenderMan points. Throughout the sequence, we were dealing with very complex simulations. The sand trails were all simulated; the stuff that is coalescing and forming into these huge masses was simulated. Doing the simulations for all of that falling, crumbling sand was extremely time-consuming. We had to run some low-rez particle simulations — roughly 100,000 particles — to do it in a timely way. Fortunately, Doug Bloom, Jon Cohen and Chris Allen came up with a method to ‘boost’ the resulting simulations and make it seem as if we had simulated several hundred million sand grains, and, at render time, instanced them to make it appear like billions.”

Sandman makes several appearances in New York City — most notably in the subway system, where black-suited *Spider-Man*, who believes Marko to be the killer of his Uncle Ben, engages him in a ruthless fight. Albert Hastings supervised the sequence, which consisted of approximately 80 shots, while Peter Giliberti was lead animator, overseeing *Spider-Man* fight moves that were more

church bell tower to rip the black symbiotic substance from his body. The production filmed Tobey Maguire on a bell tower set, grabbing and tearing at real pieces of black costume. During postproduction, Imageworks generated black goo effects, tracking them to the fabric in the live-action photography.



The black goo lands on Eddie Brock – a co-worker of Peter Parker’s – beneath the church tower, initiating his transformation into Venom. James Acheson designed the Venom suit worn by Topher Grace throughout the film. Imageworks produced a digital double for scenes in which Venom performs extreme versions of Spider-Man’s aero-acrobatics. To ensure behavioral continuity between the live and CG versions of Venom, both Topher Grace and the Imageworks animators based their performances on footage of predatory cats.

aggressive and hard-hitting than traditional *Spider-Man* animation. “This fight is a lot more brutal than what we’re used to seeing *Spider-Man* in,” noted Scott Stokdyk. “This black-suited character is much more vicious than classic *Spider-Man*, and it really shows in this fight with Sandman in the subway.”

A practical subway tunnel set served the live-action beginning of the sequence; but as the fight action intensifies, it moves into Imageworks digital environments, including a huge hub area with many levels of interconnecting tunnels. All of the subway trains in the sequence were synthetic, as well. “We actually repurposed the train that was in *Spider-Man 2* for those shots,” remarked Stokdyk. “We changed the look of it a bit, and shot new people to put inside the windows.”

As Imageworks’ workload grew, Giant Killer Robots, led by visual effects supervisor John Vegher, stepped in to create tunnel textures for approximately 30 shots within the cavernous hub environment. “This was a huge underground area,” said Vegher, “which would have been about 150 feet high in real space; and that entire space had to be created digitally. Imageworks modeled that environment, and then we textured those models. Sony has very high standards, as do we, and so all of this had to be extremely detailed. Virtually every texture in the entire place, regardless of how big or small it was area-wise, was 4K. And we actually delivered 8K textures in some cases. These were huge files we had to create for them, because they wanted the maximum flexibility when they were doing the look and lighting for their final shots.”

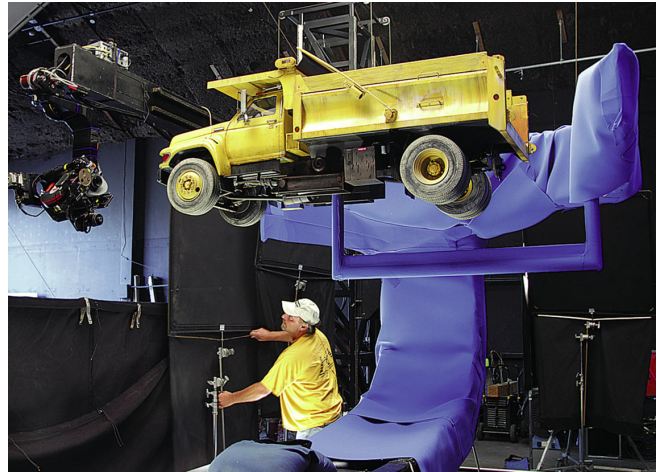
The subway fight features live, digital and bluescreen versions of *Spider-Man* and Sandman — and often a part-digital, part-live version of the latter for shots in which Sandman uses his shape-shifting capabilities to create an oversized arm and fist. Imageworks tracked sand effects to Thomas Haden Church in dynamic shots of Sandman punching *Spider-Man* with his oversized limb, sand spraying out in particle animation with the impact. In less dynamic shots, Church sometimes wore a prosthetic limb, built by Frontline.

At one point in the fight, *Spider-Man* pushes Sandman against a passing train, which causes his sand-filled head to be shaved off, layer by layer. To provide a live basis for the head-shaving shot, the crew photographed Thomas Haden Church as a stunt *Spider-Man* pushed his head against a vibrating plexiglass sheet. “That gave us the real lighting on Thomas Haden Church,” said Scott Stokdyk, “as well as the real physical effect on his body. In post, we inserted our CG train, tracked his head, and did a CG erosion effect on it, with CG particles flying off.”



In a climactic battle set at a skyscraper construction site, Spider-Man faces off with Venom, who has evolved to his most grotesque form. Frontline built an animatronic head for earlier shots of Venom opening his mouth unnaturally wide, revealing rows of monstrous teeth. When Sam Raimi decided to push the character’s physiology beyond the limits of the animatronic in those shots, Imageworks isolated the mouth area of the animatronic and tracked it to a stuntman in suit and makeup.

The fight concludes when both characters fall into a drainage area at the bottom of the track hub area — shot in a water tank on the Sony lot, with a special effects gag by John Frazier. “*Spider-Man* falls and hits a giant pipe connected to a water system, and there is an explosion of water that washes Thomas Haden Church away,” explained Stokdyk. “We put in a life-size mannequin on the set to see the effect of the water on a body as it got blown away. We also shot a separate pass of a stunt guy in place, so we could get a live person bracing for the hit — and then in the composite we swapped, at the moment of impact, the live-action stunt person with the mannequin. That was shot from multiple camera angles and then it was cut together. After Sandman is washed away into the drain, there are a couple of shots of him being pushed through a grate, dissolving into a mud-man, which used projected elements of Thomas Haden Church. He put on a black wet suit and did take after take, both underwater and above water, being pummeled back into this grate.”



A scene in the final battle features a dump truck falling from one of Venom’s giant webs, nearly crushing Mary Jane below. New Deal Studios built a quarter-scale truck, ingeniously designed to break apart in specific pieces, which could then be quickly reassembled. New Deal had to reinforce the fragile truck model when production added a shot of the vehicle falling, which required that the model be mounted on a motion control modelmover. After filming the motion control shot, New Deal removed all the reinforcements from the model, and dropped it 20 feet onto the stage floor.

Spider-Man assumes that Sandman has been destroyed; but the character reappears, several scenes later, on a sandy beach, slithering out of the water and reforming into his human shape. Working with a clean plate of the beach area and a plate with Thomas Haden Church rising to a standing position, Tweak Films and Imageworks executed a CG transformation from the mud-man form to the actor.

Alarmed by his taste for revenge, and his merciless behavior in his fight with Sandman, an anguished *Spider-Man* goes to a church tower to rip the black symbiotic substance from his body. Production filmed Tobey Maguire on a set representing the top of the church tower; Imageworks then generated goo effects and integrated them with the live-action photography, creating a shot that was featured prominently in the *Spider-Man 3* trailers.

“Spencer Cook and I worked pretty closely with Jim Acheson to figure out how to do the church tower sequence,” noted Stokdyk. “We decided that, as much as possible, we wanted the action to be physical, with Tobey actually grabbing onto something as he pulled at the black stuff; and so we tried to always have a real piece of costume there. Then, most often, we enhanced it digitally. In some cases, it was just easier to replace the whole costume digitally, rather than try to hook up black goo or pieces of black synthetic costume to the real costume. But what we never did was replace the actor’s skin with CG skin. As we were shooting, everywhere that I knew the skin of the actor was going to be revealed, I never had any costume on that area. But everywhere I knew we didn’t have to reveal skin, whether it was covered with black goo or covered with the original costume, I had the costume on the actor.”

Giant Killer Robots contributed to the church tower sequence, delivering environment and background elements over which Imageworks composited its venom effects. “We did set extensions and some bluescreen replacements,” explained John Vegher. “They had a set for the top portion of the church tower, and they had a set for the bottom portion. But the entire middle portion — five to ten floors, depending on the shot — didn’t exist; and so we created those bridge elements. We had to take the lighting out of the original plates through projections so we could relight when necessary. It involved a lot of very painstaking handwork and eyeballing things until they were just right — but we did it.”

Thomas Hutchinson served as Giant Killer Robots’ sequence lead on the church tower set extensions, among them Eddie Brock’s street-level, up-angle point of view of the tower as *Spider-Man*’s discarded black goo falls toward him. “We had to create everything of that tower, after the first ten feet,” said Vegher. “The top of that ten-foot set was a hard edge, of course, and we had to eat away at that a bit and soften it up, because there was blue spill on it. It was easier and gave us more flexibility in the lighting to start our extension a bit lower, into that area, rather than just dealing with what was actually there.”

The goo lands on Eddie Brock — a co-worker of Peter Parker’s — beneath the church tower, initiating his transformation into Venom. James Acheson designed the Venom suit worn by Topher Grace throughout the film, and oversaw its fabrication by Frontline. Frontline also produced an animatronic Venom head, originally intended for scenes in which the character’s facial structure takes on nonhuman proportions. “When Venom gets in a heightened emotional state,” explained Scott Stokdyk, “his mouth grows and he shows a lot of teeth. Originally, there were two places we thought we’d be able to use the animatronic for those kinds of transformations; but with script changes, we wound up just using the mouth portion. We shot specific angles on the animatronic mouth and composited them onto a stuntman wearing the Venom costume. For shots in which Sam wanted even more extreme mouth opening, we added CG mouths — with teeth and classic Venom tongue — to shots of the stunt guys in costume.”



Sandman, grown to gigantic proportions, joins the final battle. Regardless of the character’s size or form, Sandman’s animation was always driven by Thomas Haden Church’s performance. To guide animators for any sand effects shot with Church in the scene, the effects crew captured a variety of angles by aiming two high-definition witness cameras on the actor, in addition to the film cameras. To ensure that even all-CG versions of the character — such as Giant Sandman -- would reflect Church’s performance, Imageworks crews also arranged a facial capture session with the actor, then applied the resulting motion capture data to their digital character.

Ultimately, Venom most often was portrayed by Topher Grace in the costume and makeup for live-action scenes; and then by Imageworks’ CG double for dynamic action scenes in which Venom performs extreme versions of *Spider-Man*’s aerobatics. “If black-suited *Spider-Man* was a ramped-up version of classic *Spider-Man*,” observed Spencer Cook, “Venom was a ramped-up version of black-suited *Spider-Man*. For animating Venom, we looked at tons of reference footage of animals. Lions and cheetahs, in particular, were very good reference. We liked their aggressive, predatory

movements, and we re-created them in Venom in the way that he crouches and jumps and attacks. Everything we did for the Venom animation was based on that reference.”

Topher Grace brought similarly predatory movements to his performance, to ensure that the live-action and CG characters would match. “Throughout this picture,” said Cook, “I was very concerned with blending what the actors and stuntmen were doing with the animation, so that every character would be consistent all the way through. So, early on in the production, whenever Topher was brought in for a costume fitting, I’d be there — sometimes with Sam, sometimes not — and we’d play around a bit, acting out stuff. I would act out moves; Topher would act out moves. We were trying to find a language that would work so that the Venom character would be consistent, whether he was live or animated.”

Baited by the capture of Mary Jane by Venom — who has her held prisoner within a giant web — *Spider-Man*, joined by Harry Osborn, faces both Venom and Sandman in a nighttime battle sequence set in a construction yard. Production shot live-action footage at Chase Plaza in New York, which Imageworks re-created in CG, adding a CG building under construction that was absent from the location plates. “The final battle sequence was a great opportunity for us to exactly replicate a real location in New York,” commented Stokdyk, “which is something I’ve been pushing for since the first movie. To do that, we took extensive information from the Chase Plaza location — helicopter footage, field photography, HD video, film photography, Spydercam pan-and-tilt, Spydercam flying shots. We got the full gamut of incredible coverage; and from that we re-created this location in CG. It’s been done in other movies, of course, but we’ve never done it to this degree and this exactness in a *Spider-Man* film. I think it really helped to bring New York to the film.”



Harry reconciles with Spider-Man and joins the battle against Venom and Sandman, also rushing to Mary Jane’s rescue when she topples from one of Venom’s giant webs at the construction site. Imageworks re-created and significantly extended the Chase Plaza location where production had shot live-action plates for the final battle, gathering extensive documentation from the site that included helicopter footage, field photography, high-definition video photography, Spydercam pan-and-tilt shots and flying Spydercam plates. Though the final battle environment was primarily synthetic, Imageworks blended pieces of the location plates into its CG construction site to ground the setting in reality.

As they had for other action sequences in the film, Imageworks artists blended bits and pieces of the location plates with their CG construction site. One scene in the final battle — in which Mary Jane is nearly crushed by a falling dump truck — integrated miniature elements, as well. New Deal Studios, with Forest Fischer supervising, built an ingenious quarter-scale dump truck for the shots. “Production wanted the truck to break apart in a specific way when it hit the ground,” said Ian Hunter, “and Sandman uses those pieces as part of his body in his fight with *Spider-Man*. So it was imperative that the truck fall apart in nice big chunks. But, even though they wanted two takes, they only wanted us to build one truck; so we had to build it like toys I remember having as a kid — cars and trucks that would break apart when you slammed them into a curb or a wall, but then could be put back together. We built a chassis that was solid enough to endure the drop twice; but all of the body pieces were made to pop off. We made two beds, two cabs, two of all the breakaway

pieces that would be damaged in the fall; and then we cobbled all of those pieces back together for the second take.”

New Deal made the breakaway sections out of soft aluminum that would bend and crumple on impact. The pieces were also prescored, weakly held together with pieces of tape or very thin pins. “We used anything that would hold them together just long enough for them to make the drop,” explained Hunter. “That meant that the model was extremely delicate and fragile, which would have been fine except that partway through the build, production decided they needed an establishing shot of the truck falling before it hit the ground, which was not the original plan. They wanted to shoot our model truck motion control for a few shots; but it wasn’t solid enough to withstand being shot on a modelmover. We ended up adding a mount and reinforcing a lot of the breakaway pieces so the model could sit on a modelmover and not fall apart during the take. We also put in some really nice LED headlights so we’d get lens flares as the truck was falling.”

After shooting the motion control shot of the truck falling, New Deal removed all the reinforcements from the model, and dropped it 20 feet onto the stage floor. “To get interaction,” noted Hunter, “production had shot a plate where they dropped a piece of trench-plate onto some barrels. We dropped our truck to match that action. *Instead* of trying to motion control the cameras, we just followed the truck down as it dropped and then exploded on the stage floor. My mechanical effects guy, Scott Beverly, strung some weights on one corner of the truck; so as it fell, it did a nice, gentle roll.”

While Harry and *Spider-Man* attempt to rescue Mary Jane, they also battle Sandman and Venom, portrayed by CG versions of the characters in animation led by Chris Williams. The all-CG version of Venom featured in the final battle represents the character in his most extreme form. “The character evolves and becomes more of a monster throughout the movie,” stated Scott Stokdyk, “until, by the final battle, he’s what we called ‘comic book Venom’ — a mass of swarming black tendrils that have formed themselves into this monstrous shape. When we first took on the character, we knew that this final Venom would be the most challenging one.” John Haley oversaw the look development of the all-CG Venom, while Eric Miller executed the character rigging.

A digital Sandman also appears in the final battle in his most monstrous form, a giant entity measuring 100 feet tall. Francisco Dejesus supervised shots featuring the gigantic Sandman, while Terrance Tornberg did look development on the character. “At the end of the movie,” related Stokdyk, “Sandman uses all of the sand in the construction site to turn himself into this huge ‘Giant Sandman,’ which was one of our biggest sand challenges.”

Throughout the movie, whenever Sandman increased in size, the filmmakers took pains to justify where the extra mass came from. *In* an earlier sequence, in which Sandman runs from the police, for example, he hides in a dump truck full of sand, and emerges as a 20-foot-tall character that looks like a more diffused version of Thomas Haden Church. One of the principles Sam Raimi had laid down at the beginning of the show was that the bigger Sandman got, the less he would look like the actor — the idea being that with the absorption of more ‘regular’ sand, the less, percentage-wise, he would consist of the original smart grains that he could control. By the end of the picture, when Sandman appears as the giant creature during the final battle, his resemblance to Thomas Haden Church is minimal.

In King-Kong-vs-planes fashion, Giant Sandman swipes at Harry and *Spider-Man* as they fly through the construction site aboard Harry's sky stick. "This part of the sequence had a lot of what Sam referred to as 'Avengers comic book cover shots,'" noted Stokdyk. "They are wide scope, with the giant monster surrounded by multiple superheroes — which was typical of those comic book covers. That was the look Sam was going for in these shots."

The battle ends with the destruction of Sandman and Venom, the former collapsing into a massive mound of sand when he is hit by missiles fired from the rocket-launcher on Harry's glider. "We did some really dynamic shots of Sandman crumbling after he is hit with these missiles," stated Stokdyk. "Sandman's structure is compromised, and he stumbles and collapses as he steps forward. That was a huge mixture of particle effects and rigid body dynamics effects generated by CG artist Jamie Pilgrim. Sandman is so huge at this point, his collapse looks like the demolition of a high-rise building — huge balls of dust rolling out, with big chunks of material in between."

Recalling how sound weakened the symbiotic substance in the church bell tower, *Spider-Man* dispatches Venom by building a sound cage around the character made of pipes, and then banging on them to create the desired resonance and pitch. Once Venom is made vulnerable by the clanging, *Spider-Man* throws a pumpkin-bomb at the character, and destroys him. "At the end of the day," said Stokdyk, "it is Harry and his technology that enable *Spider-Man* to defeat both of the villains."

By the time *Spider-Man 3* appeared in theaters across the country, Scott Stokdyk had lived with Peter Parker and his crime fighting, arachnid alter ego for more than seven years. After so many years, so many shots, so many web-slingings and so many swings between skyscrapers, one might expect Stokdyk to have a 'been-there-done-that-have-the-crew-jacket' attitude about the cinematic adventures of *Spider-Man*.

But, as postproduction on *Spider-Man 3* neared its end, Stokdyk remained as enthusiastic about the effects challenges and the creative collaboration with Sam Raimi as he had been his first day of work on *Spider-Man* back in 2000. "I thought I would be thoroughly burned out on *Spider-Man* by now," Stokdyk admitted, "but I'm not — not at all. All three movies — and this latest one in particular — have had so many different kinds of effects challenges, it has been like working in three completely separate and unique effects environments. Also, *Spider-Man 3* is a very different type of story than the other two movies. Sam had something new to say with this movie, something new to say with this character; and that made the work fresh, as well. At this point, I'm tired — but I'm still excited about *Spider-Man*."

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